COMPUTER SIMULATION OF A COTTON PRODUCTION SYSTEM

Users Manual

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This publication reports work done under Regional Research Project S–69, "Engineering Systems for Cotton Production," a joint effort of the Agricultural Research Service, U.S. Department of Agriculture, and the State agricultural experiment stations of Alabama, Arizona, Arkansas, Louisiana, Mississippi, North Carolina, Oklahoma, South Carolina, Tennessee, and Texas. The State experiment station research was supported in part by allotments from the Regional Research Fund established by the Hatch Act, as amended August 11, 1955, and administered by the Cooperative State Research Service, U.S. Department of Agriculture.

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PART 1.–SCOPE AND APPLICATION

By Rex F. Colwick and James W. Jones[2]

There has been considerable interest in computer simulation of productivity, energy flow, water use, and pollution in the many different ecosystems over the earth's surface. Much of this work has been stimulated by the International Biological Program (IBP) and is oriented toward better management of the earth's resources. We report here considerable progress, independent of IBP, toward the modeling and simulation of cotton production systems.

There are several justifications for computer simulation of a large system. First, computer models focus attention on areas where knowledge is lacking and assist in the planning and management of team research. Second, these models are useful experimental aids for studying hypotheses about system relationships, allowing better understanding of the numerous components of a system and thus reducing the cost of applied research. Ultimately, in showing the relationships among system components, computer models form a base for sound management decisions and alternatives.

Our work commenced with the organization of Regional Research Project S-69, "Engineering Systems for Cotton Production," in 1968. No one researcher can have a comprehensive understanding of the structure and operation of each component of a crop production system, and this project has provided coordination among a number of researchers in developing a cotton production simulation model. Since its inception, many experimentalists have joined the effort to build data bases for submodels, and many are also using parts of the system to study large ecosystems.

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This publication describes four simulation models of subsystems in the cotton production system. These models, encompassing seedbed preparation through harvesting and ginning, were interfaced for the first computer simulation of any crop production system in October 1973.[3] Our research group is close to completing some insect management models that will soon be added to the simulation.

The first model simulates the soil-moisture profile in the seed zone (MOIST). It is a description of the moisture flux based on the conservation of water in the top 6 inches of soil. Water evaporates from a visible moisture front as the water diffuses through a layer of dry soil and is partially replaced by capillary water that moves from a moist region to a dry region in response to a moisture gradient. This model provides the moisture input to the following model, EMERGE.

EMERGE describes the germination and emergence of the seed. It is controlled by soil-moisture tension, soil temperature at the seed depth, and the mechanical impedence of the surface soil. When the model has simulated 50% seedling emergence, the plant model, SIMCOT II, is initiated.

SIMCOT II is based on conservation principles that include a carbohydrate balance, a moisture balance, and a nitrogen balance for the plant. It requires daily inputs of solar radiation, maximum and minimum air temperatures, rainfall, pan evaporation, plant population, water-holding capacity of the soil, nitrogen application rates and dates of application, and plant growth factors related to carbohydrate, water, and nitrogen balances. Daily outputs from this model include plant weight, the number of fruit, and the age and location of each fruit on the plant.

[3] Bowen, H. D., Colwick, R. F., and Batchelder, D. G. 1973. Computer simulation of crop production: Potential and hazards. Agric. Eng. 54 (10): 42–45.

Boll opening rate curves from this model can be used to initiate the harvesting process described in the last model, HARVSIM.

HARVSIM is a single-farm harvesting model that simulates passes made in the fields by the harvesters, the selection of trailers for filling, the transporting of trailers to the gin and of empty trailers to the farm, and gin backlog. An option includes twice-over harvesting in which the second harvesting of a given field occurs only if the remaining cotton would yield more than a specified amount. The model takes the cotton on through the ginning process and is capable of assigning economic values to the end product.

These models are in various stages of validation.

MOIST was verified for only one soil type and at one location primarily because the soil parameters necessary for additional verification are lacking; however, soil parameters are being developed for approximately 20 soils that represent about 80% of the cotton farmland in the United States. Some of these data should be available in 1975.

EMERGE was tested in five States for 2 or more years and produced satisfactory to excellent simulations in years in which the temperature increased progressively as the season advanced. Subsequently, a slight modification improved the simulation when a long cold period followed a warm period 2 or 3 days after planting. This modification needs more testing under various field and weather conditions.

SIMCOT II was tested at several locations, and when detailed mappings of the plant structure had been recorded twice a week and the environment had been monitored accurately, there was good correspondence between observed and simulated plant development, fruiting characteristics, and yield. More testing is needed particularly in the area of water stress, and more development is needed to apply this model to a field growth situation.

HARVSIM was tested for 2 years in the High Plains of Texas. Data for the first year show an excellent correspondence between simulation and observation. Second-year data have not been analyzed.

Although these models are in various stages of development and verification, this users manual is presented to document progress to date and to offer these models to scientists as a tool which they may use to focus attention on aspects of the system where understanding is limited. This should help them identify missing links and assign research priorities.

These models are not sufficiently developed and tested to assist cotton producers with management decisions. Such use could result in economic losses. The full management capabilities of crop simulation will not be achieved until all major crops have been modeled. Furthermore, a number of submodels dealing with insects, diseases, root development, nutrients, and water relationships will be essential for producer decisions. These are under development.

To interface crop production submodels easily, it is possible to make simplifying assumptions based on the objective of the interface. This approach was successfully used to interface the four models described herein. In figure 1–1 crop management is shown as it relates to the cotton production system. Options were designed for running any combination of the models when the user specified appropriate inputs. For example, SIMCOT II could be run alone or with EMERGE and MOIST, or MOIST could be run alone. The integrated models were run to test hypothetical situations such as a 10-day cold spell following planting, which resulted in a realistic delay in maturity and a decrease in yield.

A simulation of planting through harvesting provided very interesting results. However, the assumptions that were made will probably not be sufficient for all applications of the model. For example, MOIST and EMERGE were interfaced to provide soil-moisture values. It was assumed that (1) the seed and seedling do not alter the soil-moisture-flux equations, (2) the soil temperature can be predicted from air temperature, (3) the relative humidity can be predicted from maximum and minimum air temperatures, the dew point temperature of the previous day, and rainfall, and (4) physical impedence is known. MOIST provided a table of the hourly moisture contents at planting depth; however, EMERGE required moisture tension values in bars as input. To use the interfaced models, a soil moisture-soil tension relationship and a moisture release equation are needed for the soil being tested.

These equations are being developed for 20 soils, as mentioned above, at North Carolina

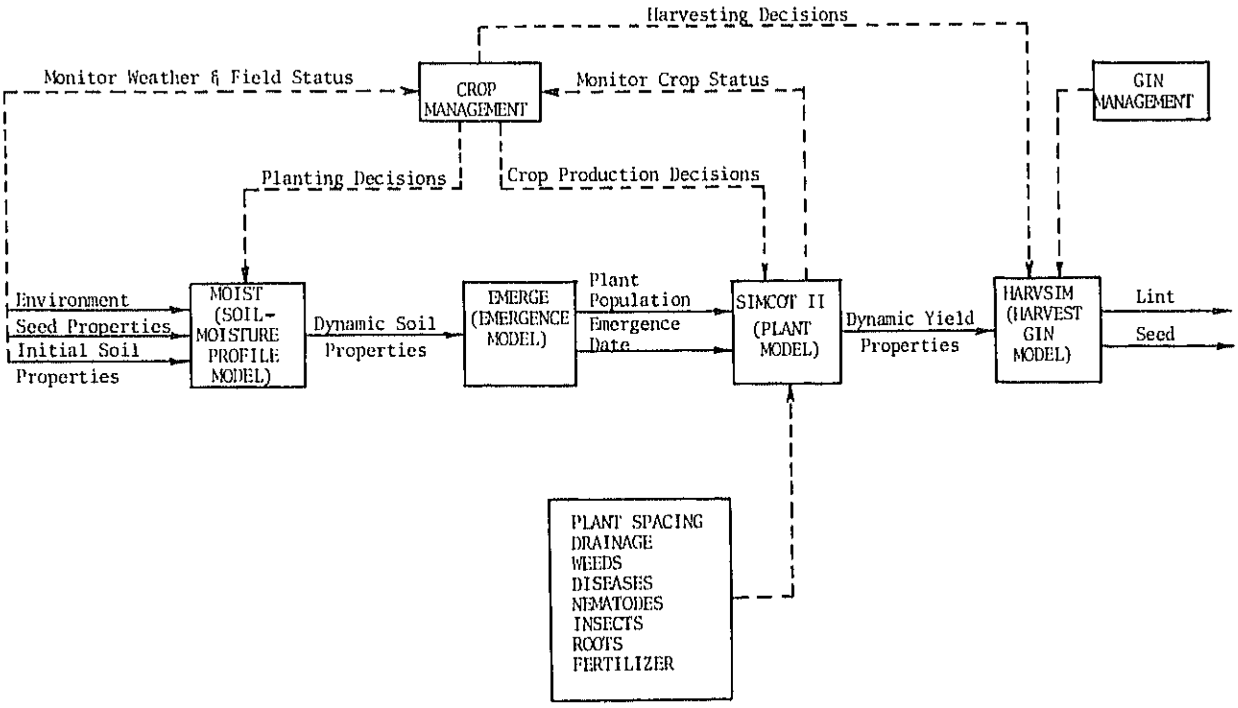

FIGURE 1-1.—Schematic of initial interface of MOIST, EMERGE, SIMCOT II, and HARVSIM.

State University. Also, Henry D. Bowen and others at North Carolina State University are attempting to obtain enough data so that EMERGE can be used without having to measure moisture, temperature, and physical impedence daily. This technique will be based on soil types and will be developed from National Weather Service information and the reaction of the soil to initializing inputs of moisture, temperature, and physical impedence.

SIMCOT II was initiated when MOIST-EMERGE predicted 50% emergence. It was assumed that from this point carbohydrate production and assimilation would be the controlling factor in plant development. A major assumption was that a single plant can be used to make predictions of growth and yield; the variability among plants, their competition, and environmental variability were not considered. Again, depending on the objective, this may or may not be suitable. Also, no insect models were integrated into this initial effort.

SIMCOT II predicted the boll opening rate used as input to HARVSIM. For this interface it was assumed that (1) no preharvest chemical aids had been used and that (2) nothing happened to the plant except the removal of open bolls. Both assumptions were based on considerable past research, but for some applications they may be unacceptable.

Considerable work remains to be done to interface these and other models at the field level. In many cases, detailed models of interactions of various physical and biological systems will be just as complicated as any of the independent models. For example, interfacing an insect population dynamics model with a crop model might be accomplished by modeling the behavior and metabolism of the insects as influenced by weather, crop factors, and insect preferences. Such an interface would allow detailed studies of the interactions and provide needed assumptions and relationships for higher level models.

An ultimate goal of these models, as mentioned earlier, is to optimize crop production systems. In addition, they will provide information for farm management decision models. Optimization models require a statement of what is to be optimized. At the producer (farm) level, profits are generally optimized (maximized) subject to the constraints particular to a given farm. However, researchers may study an optimization model designed to maximize yield or minimize production cost at the crop model level.

PART 2.—MOIST: A SIMULATION OF THE MOISTURE PROFILE OF A BARE SOIL AFTER PLANTING

By Charlie G. Coble,[1] Henry D. Bowen,[2] and Henry L. King, Jr.[3]

DESCRIPTION

MOIST is a computerized mathematical model for predicting soil water profiles during the drying of soil. It accounts for water movement in the soil in both the liquid and the vapor states and the evaporation of water to the atmosphere.

Liquid water movement is computed with the soil water diffusivity equation:

$$J_c = -D(\Theta)\frac{d\Theta}{dx},$$

where J_c=flux of water in grams per second per square centimeter,
(Θ)=soil water diffusivity in square centimeters per second,
$D(\Theta)$=water content in cubic centimeters per cubic centimeter of soil,
and $\frac{d\Theta}{dx}$=gradient of water content in cubic centimeters per cubic centimeter of soil per centimeter of distance.

The transfer of water in the vapor state because of temperature gradients is calculated with the equation

$$J_v = -D\frac{dC}{dx} - L_{ve}\frac{d(\ln T)}{dx},$$

where J_v=flux of water vapor in grams per second square centimeter,
D=diffusion coefficient of water vapor in soil matrix in square centimeters per second,
C=concentration of water vapor in soil air or atmospheric air in grams per cubic centimeter of air,
$\frac{dC}{dx}$=gradient of concentration of water vapor in soil air and in atmosphere in grams per cubic centimeter, per centimeter of distance,
L_{ve}=coupling coefficient between water vapor and heat energy in moles per second square centimeter,
T=temperature in degrees Kelvin,
and x=distance over which diffusion is occurring in centimeters.

The water evaporated to the atmosphere is controlled by vapor diffusion through the dry overlying soil layer and is calculated with the equation

$$J_e = -D\frac{dC}{dx},$$

where J_e=evaporation flux as water vapor diffusing through soil from visible moisture front to soil surface in grams per second square centimeter,
D=diffusion coefficient for water vapor through soil matrix in square centimeters per second,
and $\frac{dC}{dx}$=concentration gradient of moisture in soil air from visible moisture front to soil surface in grams per cubic centimeter per centimeter of distance.

Inputs to the simulation are weather and soil data (air temperature, atmospheric relative humidity, soil temperature, water vapor diffusion coefficients in soil, soil water diffusivities,

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soil bulk density, and energy-mass coupling coefficients).

The model was verified for use on Ruston loamy sand soil and is adaptable to other soils. It can be used to accurately assess the effect of cultural practices on the soil water content profiles in drying soil. It was used to examine the effects of bulk density, wind, liquid water conductivity barriers, and surface films on the soil water content profiles under drying conditions.

The costs of using the model to optimize a cultural practice, including the cost of empirical verification of results, are estimated to be 0.01 to 0.1 of those required for obtaining the same information by empirical methods alone.

LIMITATIONS

The major limitation of MOIST is the large number of temperatures and relative humidities required for the program. For instance, with 15 soil layers, air temperature, and relative humidity, there are 408 items per day of input. Just obtaining the data is a major operation, and then it must be punched in. However, for in-depth studies of moisture movement in the top inch of soil, these data are required. A second limitation is that the soil parameters necessary for the program are available only for a Ruston loamy sand soil.

The thermal vapor section of the program is not very important in humid regions except possibly in the surface inch or less of soil and for high-radiation conditions. For large-seed crops, such as cotton, corn, soybeans, and peanuts, this section can probably be bypassed without serious error, but it will probably be necessary for small-seed crops planted at shallow depths. Where the vapor transfer can be bypassed, it is not necessary to have temperature inputs for all layers, but only for the visible drying front, for which air and soil temperatures are required. If the thermal vapor transfer is bypassed, the mass-energy coupling coefficient also need not be obtained. By using a constant temperature throughout the soil profile, the thermal gradient is bypassed. This is usually some function of air temperature, such as TA-3. However, it is desirable that the temperature at the visible moisture front be estimated as closely as possible for accurate operation. Tests are in progress to develop estimates of temperature at the visible moisture front from air temperature, wind, a roughness coefficient, and solar radiation.

DEFINITION OF TERMS

ADC	Diffusion coefficient for the layer approximately halfway between the evaporation front and the surface to make sure it is diffusing through the dry soil.
AGRAD	Water vapor driving gradient from moisture front to the surface.
AIST	Distance from middle of Kth layer to the surface in centimeters when 1-cm-thick layers are used.
BD	Array for the bulk density of each soil layer.
CATM	Water vapor concentration of atmosphere in grams per cubic centimeter of air.
CCOEF	Energy-mass coupling coefficient.
COUPL	Array of the part of thermal vapor transfer due to the energy-mass coupling for each soil layer.
DCONST	Array of water vapor diffusion coefficient in soil for each soil layer. Computed in real function routine listed at end of program.
EVAPJ	Evaporation flux in grams per second.
FICKS	Array of the part of thermal vapor transfer due to Fick's law for each soil layer.
FVAPOR	Water flux in grams per second due to temperature gradient.
GRADC	Water vapor concentration of atmosphere in grams per cubic centimeter of air per centimeter of distance.
GRADLT	Gradient of the log of the temperature.
IP	The number of 1-cm layers in which the soil profile is divided.
IT	The total number of time periods for the model to run.
L	The first L in MOIST is k/2; it is used to select a dry layer that is over the evaporation front. The second L is a DO loop subscript.
QCOND	Array of the amount of water transferred out of each soil layer in the form of liquid water.
QCONDD	Array for each soil layer of the liquid water transferred down.
QCONDU	Array for each soil layer of the liquid water transferred up.
QEVAP	Array of the quantity of evaporated moisture.
QVAPOR	Water vapor transfer due to temperature gradient per soil layer (array).
RH	The relative humidity of the atmospheric air during the time period.
SAVE	Evaporation from moisture front.
SAVE1	Distance in centimeters from the surface of the soil to the moisture front of the soil.
SEC	The number of seconds in each time period.

SWITCH Allow moisture to evaporate from the layer with moisture front in it.

T Array for the temperature of each soil layer during the time period.

TA The temperature of the atmosphere air during the time period.

TCK Array of temperature converted to Kelvin for each soil layer.

VWC Array of volumetric water content for each soil layer in cubic centimeters of water per cubic centimeter of soil.

WATER Array of moisture level of each soil layer in grams of water per cubic centimeter of soil.

WC Array for water content of each soil layer (dry-weight basis). Example: 6%, read in as 0.06.

WDIFF Diffusivity coefficient for a particular soil.

INPUT/OUTPUT

Input

Program inputs read in as data are arranged in the following order and formats:

1. IP, IT, and SEC on one card in I10, I10, and F10.0 format.
2. BD array (bulk density of each soil layer) arranged in 15F5.0 format.
3. WC array (initial moisture content at each soil layer) arranged also in 15F5.0 format.
4. RH, TA, and T (RH and TA are single variables and T is an array) arranged in F3.0, F2.0, and 15F5.0 format.

The maximum number of soil layers is 15. If a deeper profile is needed, enlarge the dimension statement and the input and output formats.

Output

The output of the program consists of the time period, the moisture content of each level for that time period, the distance from the surface to the center of the soil layer with the moisture front, and the quantity of evaporated moisture. The output variables are J, (WC(I), I=1, IP), SAVE1, and SAVE, formated as 15, 15F7.4, F5.2, and E15.6.

PROGRAM SETUP AND EXECUTION

MOIST is written in FORTRAN G, a standardized FORTRAN supported by IBM, for the IBM 370/165 computer. The program does not use any special system functions, but is easily transformable to any FORTRAN compiler. The standard code for an IBM 370/165 is EBCDIC, and the cards were punched on an IBM 029 keypunch.

The card deck is arranged in the following sequence:

A. Control cards
   1. Job card
   2. // EXEC FTGCLG
   3. //C.SYSIN DD *
B. Main program deck
C. Function
D. Control cards
   1. /*
   2. //G.SYSIN DD *
E. Data
F. Control cards
   1. /*
   2. //

The // EXEC FTGCLG card in the control section tells the computer to compile, link and execute the program. The //C.SYSIN DD * card causes the program and the function to be compiled. All initializing of values to zero should be done in the program. All linkage to execute a FORTRAN program is then compiled. The //G.SYSIN DD * card then causes the program to be executed using the following data cards. The compiled program uses approximately 5,000 memory locations, and the execution requires 30,000 memory locations on the IBM 370/165. To simulate 4 days, the computer compile and execution times are approximately 2.0 and 5.0 seconds, respectively.

PROGRAM LISTING

```
C       THIS PROGRAM CALCULATES DISTRIBUTION OF MOISTURE DURING THE
C       DRYING STAGE
        DIMENSION BD(15), WC(15), T(16), C(16), WATER(15), QEVAP(15),
       1QVAPOR(16),QCOND(16),DCONST(15),QCONDU(16),QCONDD(15),VWC(15),
       1FICKS(15),COUPL(15),TCK(16)
        READ(1,51)IP, IT, SEC
        READ(1,52)(BD(I),I=1,IP)
        READ(1,53)(WC(I),I=1,IP)
   51   FORMAT(2I10,F10.0)
   52   FORMAT(15F5.0)
   54   FORMAT(F3.0, F2.0, 15F5.0)
   53   FORMAT(15F5.0)
   27   FORMAT(' TIME  WC(1)  WC(2)  WC(3)  WC(4   WC(5)  WC(6)  WC(7)  WC
       1(8)  WC(9) WC(10) WC(11) WC12) WC(13) WC(14) WC(15)  DIST  QEVAP')
        WRITE(3,27)
        DO 125 M=1,IP
  125   VWC(M) =  WC(M) * BD(M)
        DO 75 J=1,IT
        READ(1,54) RH,TA, (T(I),I=1,IP)
        T(16) =T(15)
        DO 75  J2=1,4
        SWITCH=0
        DO 1 K=1,16
    1   C(K)= 2.288E-6*10**((T(K)-3)/76)
C       MOISTURE TRANSFER DUE TO TEMPERATURE GRADIENTS SECTION
        DO 90  K=1,IP
        DCONST(K)= D(T(K), BD(K), WC(K))
C       THIS STATEMENT SKIPS MOISTURE TRANSFER IF MOISTURE CONTENT IS
C       LESS THAN 1%.
        IF(WC(K).LE.0.018)  GO TO 105
        CCOEF =(-0.0000067 + 0.000384*WC(K))/ 18
        GRADC =C(K)- C(K+1)
        TCK(K)=5*(T(K)-32)/9+273
        TCK(K+1)=5*(T(K+1)-32)/9+273
        GRADLT=ALOG(TCK(K)/TCK(K+1))
        FICKS(K)=DCONST(K)*GRADC
        COUPL(K)=CCOEF*GRADLT
        FVAPOR=FICKS(K)+COUPL(K)
        QVAPOR(K) = FVAPOR * SEC
        QVAPOR(K) = ABS(QVAPOR(K))
        GO TO 110
  105   QVAPOR(K) = 0
  110   CONTINUE
C       EVAPORATION SECTION
C       THIS STATEEMENT BYPASSES EVAPORATION STEP IF MOISTURE CONTENT
C        IS LESS THAN 0.5%
        IF(WC(K).LE.0.005) GO TO 80
C           THIS STATEMENT BYPASSES EVAPORATION STEP IF EVAPORATION HAS BEEN
C       CALCULATED FOR A HIGHER SLICE
        IF(SWITCH.EQ.1) GO TO 80
        CATM = 2.288E-6 * 10**((TA-3)/76)*RH
        DIST=K-0.5
        SAVE1 = DIST
        AGRAD=(C(K)- CATM)/ DIST
        L=K/2
        IF(L.LE.1) L= 1
        ADC=DCONST(L)
        EVAPJ = ADC*AGRAD
        QEVAP(K) = EVAPJ * SEC
        QEVAP(K) = ABS(QEVAP(K))
        SAVE = QEVAP(K)
        SWITCH=1
```

```
      GO TO 70
   80 QEVAP(K) = 0
      L=0
      DIST=0
      AGRAD=0
      ADC=0
      EVAPJ=0
C     THIS SECTION COMPUTES WATER TRANSFERRED DUE TO HYDRAULIC CONDUCTIVITY
70    IF(VWC(K).LE.0.02) GO TO 480
      IF(VWC(K).LE.0.055) GO TO 135
      WDIFF=(10**((VWC(K) - 0.046) / 0.036))* 0.00001
      GO TO 91
  135 WDIFF = 1.55E-5
      GO TO 91
480   WDIFF=0.0
   91 IF(K.EQ. 1) GO TO 11
      IF(WC(K) -WC(K-1)) 11,11,12
   12 QCONDU(K) = WDIFF * (VWC(K) - VWC(K-1)) * SEC
      GO TO 15
   11 QCONDU(K) = 0
   15 IF(K.EQ.15) GO TO 13
      IF(WC(K) - WC(K+1)) 13,13,14
   14 QCONDD(K) = WDIFF * ( VWC(K) - VWC(K+1)) * SEC
      GO TO 16
   13 QCONDD(K) = 0
   16 QCONDU (16)=0
   90 CONTINUE
430   DO 18 N=1,15
      IF(N .EQ. 1) GO TO 17
      QCOND(N) = -QCONDD(N) - QCONDU(N) +QCONDU(N+1) + QCONDD(N-1)
      GO TO 18
   17 QCOND(N) = - QCONDD(N) + QCONDU(N+1)
   18 CONTINUE
      DO 65 L=1,15
      WATER(L) = WC(L)*BD(L)
      IF(T(L) - T(L+1))45,40,40
   40 IF(L.EQ.1) GO TO 100
      WATER(L) = WATER(L) - QEVAP(L) - QVAPOR(L) + QCOND(L)+ QVAPOR(L-1)
      GO TO 50
  100 WATER(L) = WATER(L) - QEVAP(L) - QVAPOR(L) + QCOND(L)
      GO TO 50
   45 WATER(L) = WATER(L) - QEVAP(L)+QCOND(L)- QVAPOR(L)
     1+ QVAPOR(L+1)
   50 IF(WATER(L).LE.0)  WATER(L) = 0
      WC(L) = WATER(L)/BD(L)
      VWC(L) = WATER(L)
   65 CONTINUE
      WC(15) =  WC(14) + WC(14) - WC(13)
   75 WRITE(3,26) J, WC(1), WC(2), WC(3), WC(4), WC(5), WC(6), WC(7),
     1WC(8), WC(9), WC(10), WC(11), WC(12), WC(13), WC(14), WC(15),
     1SAVE1,SAVE
   26 FORMAT(I5,15F7.4,F5.2,E15.6)
      RETURN
      END
      REAL FUNCTION D(T, BD, WC)
      TK =T+460
      E=0.286*((TK/492)**1.75)
      F=BD/2.65 + (WC*BD)
      F1=1.0-F-0.23
      D=E*F1
      RETURN
      END
```

EXAMPLE RUN
Input Data

For read statement	Field 1	Field 2	Field 3	Field 4	Field 5	...	Field 14	Field 15	Field 16	Field 17
Read (1,51) IP,IT,SEC	15	79	900			...				
Read (1,52) (BD (I),I=1,IP)	1.08	1.08	1.08	1.08	1.08	...	1.3	1.3		
Read (1,53) (WC (I),I=1,IP)	0.0703	0.0703	0.0703	0.0703	0.0703	...	0.0703	0.0703		
	RH	TA	T (1)	T (2)	T (3)	...	T (12)	T (13)	T (14)	T (15)
Read (1,54) RH,TA,(T (I),I=1,IP)	0.28	74	58	58	58	...	60	61	61	61
	0.28	73	61	60	60	...	60	61	62	63
	0.22	81	68	68	67	...	64	64	64	65

Output Data

$DATA

TIME	WC(1)	WC(2)	WC(3)	WC(4)	WC(5)	WC(6)	WC(7)	WC(8)	WC(9)	WC(10)	WC(11)	WC12)	WC(13)	WC(14)	WC(15)	DIST	QEVAP
1	0.0693	0.0703	0.0703	0.0703	0.0703	0.0703	0.0703	0.0703	0.0703	0.0703	0.0703	0.0703	0.0703	0.0703	0.0703	0.50	0.106599E-02
1	0.0684	0.0702	0.0703	0.0702	0.0712	0.0696	0.0703	0.0703	0.0703	0.0703	0.0703	0.0703	0.0703	0.0703	0.0703	0.50	0.106996E-02
1	0.0675	0.0701	0.0703	0.0703	0.0720	0.0690	0.0702	0.0703	0.0703	0.0703	0.0703	0.0703	0.0703	0.0703	0.0703	0.50	0.107370E-02
1	0.0667	0.0700	0.0703	0.0704	0.0727	0.0686	0.0700	0.0702	0.0703	0.0703	0.0703	0.0703	0.0703	0.0703	0.0703	0.50	0.107724E-02
2	0.0656	0.0698	0.0703	0.0705	0.0732	0.0682	0.0698	0.0702	0.0703	0.0703	0.0703	0.0703	0.0703	0.0703	0.0703	0.50	0.130920E-02
2	0.0646	0.0696	0.0703	0.0707	0.0737	0.0679	0.0696	0.0702	0.0703	0.0703	0.0703	0.0703	0.0703	0.0703	0.0702	0.50	0.131430E-02
2	0.0637	0.0694	0.0702	0.0709	0.0741	0.0676	0.0694	0.0701	0.0703	0.0703	0.0703	0.0703	0.0703	0.0703	0.0702	0.50	0.131917E-02
2	0.0627	0.0692	0.0702	0.0711	0.0744	0.0674	0.0692	0.0701	0.0703	0.0703	0.0703	0.0703	0.0703	0.0702	0.0702	0.50	0.132385E-02
3	0.0613	0.0688	0.0702	0.0713	0.0748	0.0672	0.0691	0.0700	0.0702	0.0703	0.0703	0.0703	0.0703	0.0702	0.0702	0.50	0.189652E-02
3	0.0600	0.0685	0.0702	0.0715	0.0751	0.0671	0.0690	0.0699	0.0702	0.0703	0.0703	0.0703	0.0703	0.0702	0.0702	0.50	0.190620E-02
3	0.0587	0.0681	0.0702	0.0717	0.0753	0.0669	0.0688	0.0698	0.0702	0.0703	0.0703	0.0703	0.0703	0.0702	0.0701	0.50	0.191559E-02
3	0.0574	0.0677	0.0702	0.0718	0.0755	0.0668	0.0687	0.0697	0.0701	0.0703	0.0703	0.0703	0.0703	0.0702	0.0701	0.50	0.192475E-02
4	0.0554	0.0673	0.0701	0.0721	0.0757	0.0667	0.0686	0.0696	0.0701	0.0702	0.0702	0.0703	0.0702	0.0702	0.0702	0.50	0.252650E-02
4	0.0535	0.0670	0.0700	0.0723	0.0759	0.0667	0.0685	0.0695	0.0701	0.0702	0.0702	0.0703	0.0702	0.0702	0.0702	0.50	0.254434E-02
4	0.0516	0.0665	0.0699	0.0724	0.0760	0.0666	0.0684	0.0694	0.0700	0.0702	0.0702	0.0702	0.0702	0.0702	0.0703	0.50	0.256170E-02
4	0.0498	0.0661	0.0699	0.0726	0.0762	0.0665	0.0683	0.0693	0.0700	0.0702	0.0701	0.0702	0.0702	0.0703	0.0703	0.50	0.257868E-02
5	0.0472	0.0655	0.0698	0.0728	0.0763	0.0665	0.0682	0.0692	0.0699	0.0701	0.0702	0.0702	0.0702	0.0703	0.0703	0.50	0.351497E-02
5	0.0447	0.0649	0.0697	0.0730	0.0764	0.0664	0.0682	0.0692	0.0699	0.0701	0.0702	0.0702	0.0703	0.0703	0.0703	0.50	0.354667E-02
5	0.0421	0.0643	0.0696	0.0731	0.0765	0.0663	0.0681	0.0691	0.0698	0.0700	0.0701	0.0702	0.0703	0.0703	0.0702	0.50	0.357800E-02
5	0.0396	0.0636	0.0695	0.0732	0.0766	0.0663	0.0680	0.0690	0.0698	0.0700	0.0701	0.0702	0.0703	0.0703	0.0702	0.50	0.360910E-02
6	0.0363	0.0630	0.0694	0.0733	0.0768	0.0662	0.0679	0.0690	0.0697	0.0700	0.0702	0.0702	0.0703	0.0702	0.0702	0.50	0.448423E-02
6	0.0330	0.0623	0.0693	0.0733	0.0769	0.0662	0.0679	0.0690	0.0696	0.0700	0.0702	0.0702	0.0703	0.0702	0.0702	0.50	0.453430E-02
6	0.0297	0.0616	0.0691	0.0734	0.0770	0.0662	0.0678	0.0689	0.0696	0.0699	0.0702	0.0702	0.0703	0.0702	0.0701	0.50	0.458422E-02
6	0.0264	0.0609	0.0690	0.0734	0.0771	0.0661	0.0678	0.0688	0.0695	0.0699	0.0701	0.0702	0.0703	0.0702	0.0701	0.50	0.463413E-02
7	0.0221	0.0603	0.0688	0.0735	0.0771	0.0662	0.0677	0.0688	0.0695	0.0699	0.0701	0.0701	0.0703	0.0702	0.0701	0.50	0.569379E-02
7	0.0177	0.0596	0.0687	0.0735	0.0771	0.0662	0.0677	0.0687	0.0694	0.0699	0.0701	0.0701	0.0703	0.0702	0.0700	0.50	0.577410E-02
7	0.0135	0.0587	0.0685	0.0735	0.0772	0.0662	0.0676	0.0687	0.0694	0.0698	0.0701	0.0701	0.0703	0.0701	0.0700	0.50	0.585458E-02
7	0.0092	0.0579	0.0683	0.0735	0.0772	0.0662	0.0676	0.0686	0.0694	0.0698	0.0700	0.0701	0.0703	0.0701	0.0700	0.50	0.593185E-02
8	0.0040	0.0570	0.0681	0.0735	0.0772	0.0661	0.0676	0.0686	0.0693	0.0697	0.0700	0.0702	0.0703	0.0701	0.0700	0.50	0.704744E-02
8	0.0053	0.0540	0.0678	0.0735	0.0772	0.0661	0.0676	0.0686	0.0693	0.0697	0.0700	0.0702	0.0703	0.0701	0.0699	1.50	0.222132E-02
8	0.0000	0.0536	0.0675	0.0734	0.0773	0.0661	0.0676	0.0685	0.0692	0.0696	0.0700	0.0702	0.0703	0.0701	0.0699	0.50	0.713343E-02
8	0.0010	0.0510	0.0672	0.0734	0.0773	0.0661	0.0676	0.0685	0.0692	0.0696	0.0700	0.0702	0.0702	0.0701	0.0699	1.50	0.224794E-02
9	0.0018	0.0485	0.0668	0.0733	0.0772	0.0662	0.0675	0.0685	0.0691	0.0696	0.0699	0.0703	0.0702	0.0701	0.0700	1.50	0.242349E-02
9	0.0025	0.0463	0.0663	0.0733	0.0772	0.0662	0.0675	0.0684	0.0691	0.0696	0.0699	0.0703	0.0701	0.0701	0.0700	1.50	0.241768E-02
9	0.0031	0.0442	0.0659	0.0731	0.0771	0.0663	0.0674	0.0684	0.0690	0.0696	0.0698	0.0703	0.0701	0.0701	0.0700	1.50	0.241296E-02
9	0.0037	0.0422	0.0654	0.0730	0.0771	0.0663	0.0674	0.0684	0.0690	0.0696	0.0698	0.0703	0.0701	0.0701	0.0700	1.50	0.240853E-02
10	0.0042	0.0401	0.0649	0.0729	0.0771	0.0662	0.0674	0.0683	0.0690	0.0696	0.0698	0.0702	0.0701	0.0701	0.0700	1.50	0.244928E-02
10	0.0047	0.0382	0.0644	0.0727	0.0771	0.0662	0.0674	0.0683	0.0689	0.0696	0.0698	0.0702	0.0701	0.0701	0.0700	1.50	0.244532E-02
10	0.0052	0.0363	0.0638	0.0726	0.0771	0.0662	0.0674	0.0683	0.0689	0.0695	0.0698	0.0701	0.0701	0.0701	0.0701	1.50	0.244162E-02
10	0.0000	0.0368	0.0633	0.0724	0.0771	0.0661	0.0673	0.0682	0.0689	0.0695	0.0698	0.0701	0.0701	0.0701	0.0701	0.50	0.784429E-02
11	0.0005	0.0353	0.0629	0.0723	0.0770	0.0660	0.0673	0.0683	0.0688	0.0695	0.0698	0.0701	0.0702	0.0701	0.0701	1.50	0.202971E-02
11	0.0010	0.0338	0.0625	0.0721	0.0769	0.0659	0.0672	0.0683	0.0688	0.0694	0.0697	0.0700	0.0702	0.0702	0.0701	1.50	0.202660E-02
11	0.0015	0.0324	0.0621	0.0719	0.0769	0.0659	0.0672	0.0683	0.0688	0.0694	0.0697	0.0700	0.0702	0.0702	0.0702	1.50	0.202367E-02
11	0.0019	0.0311	0.0616	0.0717	0.0768	0.0658	0.0671	0.0683	0.0688	0.0693	0.0697	0.0700	0.0702	0.0702	0.0702	1.50	0.202090E-02
12	0.0023	0.0302	0.0612	0.0715	0.0765	0.0658	0.0671	0.0682	0.0688	0.0693	0.0696	0.0700	0.0702	0.0702	0.0702	1.50	0.163955E-02
12	0.0027	0.0293	0.0608	0.0713	0.0763	0.0658	0.0670	0.0681	0.0688	0.0693	0.0696	0.0700	0.0701	0.0702	0.0703	1.50	0.163755E-02
12	0.0031	0.0284	0.0604	0.0711	0.0761	0.0658	0.0670	0.0681	0.0688	0.0693	0.0696	0.0700	0.0701	0.0702	0.0703	1.50	0.163564E-02
12	0.0034	0.0275	0.0601	0.0709	0.0759	0.0658	0.0670	0.0680	0.0687	0.0692	0.0696	0.0700	0.0701	0.0702	0.0703	1.50	0.163382E-02
13	0.0037	0.0269	0.0597	0.0706	0.0758	0.0657	0.0669	0.0680	0.0687	0.0692	0.0696	0.0699	0.0701	0.0702	0.0703	1.50	0.138995E-02
13	0.0041	0.0262	0.0594	0.0704	0.0756	0.0657	0.0669	0.0680	0.0686	0.0692	0.0695	0.0699	0.0702	0.0703	0.0704	1.50	0.138854E-02
13	0.0044	0.0256	0.0590	0.0702	0.0755	0.0656	0.0669	0.0680	0.0686	0.0692	0.0695	0.0698	0.0702	0.0703	0.0704	1.50	0.138719E-02

13	0.0047	0.0249	0.0587	0.0700	0.0753	0.0656	0.0668	0.0679	0.0686	0.0692	0.0695	0.0698	0.0701	0.0703	0.0704	1.50	0.138590E-02
14	0.0050	0.0245	0.0584	0.0698	0.0752	0.0654	0.0669	0.0679	0.0686	0.0691	0.0695	0.0698	0.0701	0.0703	0.0705	1.50	0.114205E-02
14	0.0052	0.0241	0.0581	0.0697	0.0750	0.0653	0.0668	0.0678	0.0686	0.0691	0.0695	0.0698	0.0701	0.0703	0.0705	1.50	0.114107E-02
14	0.0025	0.0247	0.0578	0.0695	0.0749	0.0652	0.0668	0.0678	0.0685	0.0690	0.0695	0.0698	0.0701	0.0703	0.0705	0.50	0.328325E-02
14	0.0028	0.0242	0.0576	0.0693	0.0747	0.0651	0.0668	0.0678	0.0685	0.0690	0.0695	0.0698	0.0701	0.0704	0.0706	1.50	0.114971E-02
15	0.0031	0.0238	0.0574	0.0692	0.0746	0.0651	0.0667	0.0678	0.0685	0.0690	0.0694	0.0698	0.0701	0.0703	0.0706	1.50	0.100465E-02
15	0.0033	0.0234	0.0571	0.0690	0.0744	0.0650	0.0667	0.0677	0.0684	0.0690	0.0694	0.0698	0.0701	0.0703	0.0706	1.50	0.100374E-02
15	0.0036	0.0231	0.0569	0.0688	0.0743	0.0650	0.0666	0.0677	0.0684	0.0690	0.0694	0.0698	0.0701	0.0703	0.0705	1.50	0.100287E-02
15	0.0039	0.0227	0.0567	0.0687	0.0742	0.0649	0.0665	0.0676	0.0683	0.0690	0.0693	0.0698	0.0701	0.0703	0.0705	1.50	0.100202E-02
16	0.0042	0.0224	0.0566	0.0684	0.0741	0.0648	0.0665	0.0676	0.0683	0.0690	0.0694	0.0697	0.0701	0.0703	0.0705	1.50	0.916429E-03
16	0.0044	0.0221	0.0564	0.0682	0.0740	0.0648	0.0664	0.0675	0.0683	0.0690	0.0694	0.0697	0.0701	0.0703	0.0705	1.50	0.915705E-03
16	0.0047	0.0218	0.0562	0.0680	0.0739	0.0647	0.0664	0.0675	0.0683	0.0690	0.0694	0.0697	0.0701	0.0703	0.0704	1.50	0.915003E-03
16	0.0049	0.0215	0.0560	0.0678	0.0738	0.0647	0.0663	0.0675	0.0682	0.0689	0.0693	0.0697	0.0701	0.0703	0.0704	1.50	0.914322E-03
17	0.0051	0.0213	0.0558	0.0676	0.0737	0.0646	0.0663	0.0674	0.0682	0.0689	0.0694	0.0697	0.0701	0.0703	0.0704	1.50	0.871972E-03
17	0.0029	0.0218	0.0557	0.0674	0.0736	0.0645	0.0662	0.0674	0.0682	0.0688	0.0694	0.0697	0.0701	0.0702	0.0704	0.50	0.261408E-02
17	0.0032	0.0215	0.0555	0.0673	0.0735	0.0645	0.0662	0.0674	0.0682	0.0688	0.0694	0.0697	0.0701	0.0702	0.0704	1.50	0.877151E-03
17	0.0035	0.0212	0.0553	0.0671	0.0734	0.0644	0.0661	0.0673	0.0682	0.0688	0.0693	0.0697	0.0700	0.0702	0.0704	1.50	0.876457E-03
18	0.0037	0.0209	0.0552	0.0670	0.0732	0.0643	0.0661	0.0673	0.0681	0.0688	0.0693	0.0697	0.0700	0.0702	0.0704	1.50	0.835330E-03
18	0.0039	0.0206	0.0550	0.0668	0.0731	0.0643	0.0660	0.0672	0.0681	0.0688	0.0692	0.0697	0.0700	0.0702	0.0704	1.50	0.834709E-03
18	0.0042	0.0203	0.0548	0.0667	0.0730	0.0642	0.0660	0.0672	0.0681	0.0687	0.0692	0.0697	0.0700	0.0702	0.0703	1.50	0.834107E-03
18	0.0044	0.0201	0.0547	0.0665	0.0729	0.0642	0.0659	0.0672	0.0681	0.0687	0.0692	0.0696	0.0700	0.0702	0.0703	1.50	0.833522E-03
19	0.0046	0.0198	0.0545	0.0664	0.0728	0.0641	0.0659	0.0671	0.0680	0.0687	0.0692	0.0696	0.0700	0.0702	0.0703	1.50	0.832955E-03
19	0.0048	0.0195	0.0543	0.0663	0.0727	0.0640	0.0658	0.0671	0.0680	0.0687	0.0692	0.0696	0.0700	0.0702	0.0703	1.50	0.832406E-03
19	0.0050	0.0192	0.0541	0.0662	0.0726	0.0640	0.0658	0.0671	0.0680	0.0686	0.0692	0.0696	0.0700	0.0702	0.0703	1.50	0.831875E-03
19	0.0029	0.0197	0.0539	0.0661	0.0725	0.0639	0.0658	0.0670	0.0679	0.0686	0.0691	0.0695	0.0700	0.0701	0.0703	0.50	0.249408E-02
20	0.0032	0.0194	0.0538	0.0660	0.0724	0.0639	0.0657	0.0670	0.0679	0.0686	0.0691	0.0695	0.0699	0.0701	0.0703	1.50	0.836669E-03
20	0.0034	0.0191	0.0536	0.0659	0.0723	0.0638	0.0657	0.0670	0.0679	0.0686	0.0691	0.0695	0.0699	0.0701	0.0703	1.50	0.836079E-03
20	0.0036	0.0187	0.0534	0.0658	0.0722	0.0638	0.0656	0.0669	0.0679	0.0686	0.0691	0.0695	0.0699	0.0701	0.0703	1.50	0.835510E-03
20	0.0038	0.0184	0.0533	0.0657	0.0721	0.0637	0.0656	0.0669	0.0678	0.0685	0.0691	0.0695	0.0699	0.0701	0.0703	1.50	0.834960E-03
21	0.0038	0.0183	0.0531	0.0656	0.0721	0.0636	0.0655	0.0669	0.0678	0.0685	0.0691	0.0695	0.0699	0.0701	0.0703	1.50	0.834429E-03
21	0.0038	0.0182	0.0530	0.0655	0.0720	0.0636	0.0655	0.0668	0.0678	0.0685	0.0690	0.0694	0.0699	0.0701	0.0703	1.50	0.834429E-03
21	0.0038	0.0180	0.0529	0.0654	0.0719	0.0635	0.0654	0.0668	0.0678	0.0685	0.0690	0.0694	0.0699	0.0701	0.0703	1.50	0.834429E-03
21	0.0038	0.0179	0.0527	0.0653	0.0718	0.0635	0.0654	0.0667	0.0677	0.0685	0.0690	0.0694	0.0699	0.0701	0.0704	1.50	0.834429E-03
22	0.0038	0.0179	0.0526	0.0651	0.0718	0.0634	0.0654	0.0667	0.0677	0.0684	0.0690	0.0694	0.0698	0.0701	0.0704	1.50	0.693277E-03
22	0.0038	0.0179	0.0525	0.0649	0.0717	0.0634	0.0653	0.0667	0.0677	0.0684	0.0690	0.0694	0.0698	0.0701	0.0704	1.50	0.693277E-03
22	0.0038	0.0179	0.0524	0.0648	0.0716	0.0633	0.0653	0.0666	0.0676	0.0683	0.0690	0.0694	0.0698	0.0701	0.0704	1.50	0.693277E-03
22	0.0038	0.0178	0.0523	0.0646	0.0716	0.0633	0.0652	0.0666	0.0676	0.0683	0.0690	0.0694	0.0698	0.0701	0.0704	1.50	0.693277E-03
23	0.0038	0.0178	0.0522	0.0645	0.0715	0.0632	0.0652	0.0666	0.0676	0.0683	0.0690	0.0694	0.0698	0.0701	0.0704	1.50	0.708998E-03
23	0.0038	0.0177	0.0521	0.0644	0.0714	0.0632	0.0651	0.0665	0.0675	0.0683	0.0690	0.0694	0.0698	0.0701	0.0704	1.50	0.708998E-03
23	0.0038	0.0177	0.0520	0.0643	0.0714	0.0632	0.0651	0.0665	0.0675	0.0683	0.0690	0.0694	0.0698	0.0701	0.0704	1.50	0.708998E-03
23	0.0038	0.0176	0.0519	0.0642	0.0713	0.0631	0.0651	0.0665	0.0675	0.0682	0.0689	0.0694	0.0698	0.0701	0.0704	1.50	0.708998E-03
24	0.0038	0.0175	0.0518	0.0640	0.0712	0.0631	0.0650	0.0664	0.0675	0.0682	0.0689	0.0694	0.0697	0.0701	0.0704	1.50	0.708998E-03
24	0.0038	0.0175	0.0517	0.0639	0.0711	0.0630	0.0650	0.0664	0.0674	0.0682	0.0689	0.0694	0.0697	0.0701	0.0704	1.50	0.708998E-03
24	0.0038	0.0174	0.0516	0.0638	0.0711	0.0630	0.0649	0.0664	0.0674	0.0682	0.0689	0.0694	0.0697	0.0700	0.0704	1.50	0.708998E-03
24	0.0038	0.0173	0.0515	0.0637	0.0710	0.0629	0.0649	0.0663	0.0674	0.0681	0.0689	0.0693	0.0697	0.0700	0.0704	1.50	0.708998E-03

PART 3.–EMERGE: A SIMULATION OF COTTON GERMINATION AND EMERGENCE

By D. F. Wanjura[1]

DESCRIPTION

The following pages contain a short description and detailed instructions for using the computer model of cotton emergence, EMERGE. A comprehensive discussion of the theory and logic utilized in EMERGE is given by Wanjura et al.[2] Validation of EMERGE and its application for studying the sensitivity of cotton emergence to several soil parameters have been documented by Wanjura.[3]

EMERGE simulates the time distribution of cotton seedling emergence. Theoretical equations that describe water absorption by seeds and elongation of the cotton hypocotyl, with accompanying logic, form the basis of the model. Parameter values for the theoretical equations and the logic were derived from experimental data and other observations obtained from emergence tests conducted under controlled environmental conditions. Parameter values in the equations are dependent functions of the soil environment. In this manner the equations reflect the effect of temperature, moisture, and physical impedance of the soil on the emerging seedlings

Cotton emergence is divided into two phases in EMERGE. Within each phase the average performance of a population of emerging seedlings is described. The first phase is germination, which is followed by the second phase, called emergence. Germination extends from the time of planting until the average radicle length reaches 3 mm. Germination progress is related to water absorption rate, which is dependent on soil temperature and moisture. Water absorption rate increases between 60° and 100° F, but is assumed to stop below 60° F and level off above 100° F. Germination (or 3-mm radicle length) is considered to have occurred when the moisture content of the seed exceeds a specific level for a given temperature and soil moisture. These specific seed-moisture levels were determined from empirical data.

Emergence begins with the completion of germination and depends on soil temperature, moisture, and physical impedance. Emergence progress is related to the average hypocotyl elongation of the seedling population. The temperature limits for hypocotyl elongation are 60° and 104° F. Temperatures outside this range are assumed to stop or interrupt hypocotyl elongation.

Seedling emergence is calculated from a set of regression equations. These equations were developed from experimental data relating average hypocotyl length and soil-moisture level to the percentage of seedlings which exceed certain specific lengths. In the model, the specific lengths represent planting depths. For example, if the hypocotyl elongation portion of the model indicates average hypocotyl length as 4 cm, with a planting depth of 3.8 cm, and if the percentage of seedlings equal to or greater than 3.8 cm in length is 50%, as calculated with the appropriate regression equation, then 50% emergence has occurred from a 3.8-cm planting depth. Percentage emergence, of course, would be lower if the planting depth was greater for the same average hypocotyl length.

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[2] Wanjura, D. F., Buxton, D. R., and Stapleton, H. N. 1973. A model for describing cotton growth during emergence. Trans. ASAE (Am. Soc. Agric. Eng.) 16: 227–231.

[3] Wanjura, D. F. 1973. Effect of physical soil properties on cotton emergence: Prediction and quantitative description. U.S. Dep. Agric. Tech. Bull. No. 1481, 20 pp.

LIMITATIONS

The temperature range of EMERGE extends from 60° to 104° F. Soil temperatures are measured hourly at seed level.

Soil-moisture tension can vary from 0.33 to 11 bars. Soil moisture should be sampled in the interval including seed depth ±0.64 cm at least every 2 days. When the soil dries to seed depth after germination, soil moisture should then be sampled in the zone where the seedling radicle is absorbing moisture from the soil.

Soil physical impedance is the input parameter most difficult to describe numerically. The values used in developing EMERGE were measurements made in soil that was uniformly compacted from seed level to the soil surface. Even though the same type of soil penetrometer (0.4-cm-diameter blunt end) is used both in the field and in the laboratory, the same physical impedance reading on the penetrometer could represent different magnitudes of soil resistance to seedling emergence. Rarely in the field is the physical impedance level in the soil uniformly distributed with depth. The permissible range of physical impedance values for the covering soil over the seed is 3.3 to 50 lb/in^2 (PI in program). Physical impedance should be measured by inserting the penetrometer 2.5 cm into the covering soil over the seed drill. Measurements should be taken at least every 2 days

Planting depth designations are limited to 1.25-cm increments between 1.3 and 7.5 cm. If the depth of soil over the seed changes after planting, the time of change and the amount must be reflected in the computer coding of EMERGE where planting depth (DEPTH) is specified.

There is no algorithm in EMERGE to describe changes in seed vigor that may occur after planting. Thus, if long periods of adverse temperature or saturated soil are encountered, EMERGE may produce an inaccurate simulation because seed germination percentage has changed. The model was developed from experimental data on acid-delinted seed; however, it should be suitable for situations where fuzzy seed is planted.

Henry D. Bowen and James W. Jones at North Carolina State University suggest the following modification of EMERGE. The present method of calculating the limits of hypocotyl elongation (EST) for a low-temperature period followed by a warm period predicts lower growth rates than observed. If EST is calculated by using a running average, the accuracy for the above conditions is improved. At the same time, the accuracy under normal warming conditions is not affected. North Carolina has programed EMERGE for IBM 360 FORTRAN with the option of EST being calculated with or without using a running average.

DEFINITION OF TERMS

A	Array of hourly seed-level soil temperatures in degrees Fahrenheit.
CLOK	Counter for accumulating time in hours.
DE	Hypocotyl elongation during 1 hour, in centimeters.
DELMOS	Seed-moisture increase during the hour preceding germination.
DEPTH	Planting depth in centimeters.
DT	Array for storing the calculated hourly fractional accumulated increments of growing time prior to printing as output.
DWATER	Hourly increase in seed moisture in percent, dry weight.
EL	Array for storing accumulated hypocotyl lengths in centimeters prior to printing as output.
ELONG	Accumulated length of hypocotyl in centimeters.
ELST	Accumulated hypocotyl length in centimeters.
EM	Array for storing hourly EST values prior to printing as output.
EP	Array for storing cumulative percentage emergence values prior to printing as output.
EST	A three-dimensional array of maximum hypocotyl lengths used to calculate hypocotyl elongation.
GERMT	Elapsed time from planting when germination occurs in hours.
GP	Standard seed germination in percent.
IDATE	Date of test.
J	Counter for accumulating time in hours.
KL	Parameter used in calculating rate of seed-moisture uptake.
KNL	Array for storing hourly KT values prior to printing as output.
KT	A three-dimensional array of rate of elongation parameter values used to calculate hypocotyl elongation.
M	Seed-level soil-moisture tension in bars.

MOIST	Subroutine in which time variation of seed-level soil moisture is specified.
NDEPTH	Integer value of DEPTH.
PI	Soil physical impedance in pounds per square inch.
PLACE	Variable for identifying location of test.
S	TEMP.
TEMP	Seed-level soil temperature in degrees Celsius.
TIM	Time in hours.
TIME	Array for storing time values in hours prior to printing as output.
TMAX	Total allowable emergence time for the soil environmental conditions existing during the hour.
TWATER	Accumulated seed moisture in percent, dry weight.
TWATERL	Parameter for temporarily storing the value of accumulated seed moisture in percent, dry weight.

INPUT/OUTPUT

Input

Program inputs read in as data are arranged in the following order and formats:

1. A table of KT values is read under 5F 10.0 format. These data are included with the source deck, which can be obtained from the author. The KT values do not appear in the output section.

2. A table of EST values is read under 5F 10.0 format. These data are also included with the source deck and do not appear in the output section.

The following data must appear in sequence after input 2 and be supplied by the user:

3. PLACE, M, PI, IDATE, DEPTH, and GP on one card in A10, F5.0, F5.0, 5X, A10, and 2F5.2 format.

4. A-array (hourly seed-level soil temperatures) arranged in 16F5.0 format on each card. The last card should have 9999. punched in the first five spaces. The number of hours simulated is equal to the number of A-array values. A maximum of 500 values may be specified.

The following information is required input, but does not appear in the data section of the program deck; necessary changes must be made directly in the main program.

5. The variation of seed-level soil moisture (M) over time is specified in subroutine MOIST. This information must be supplied by the user in FORTRAN statements.

6. Physical impedance (PI) variation over time is specified in the main program where indicated by comment cards. The change in physical impedance must be described by the user in FORTRAN statements.

Output

The first information printed out is identifying data for the simulation, including location, beginning seed-level soil moisture, initial soil physical impedance, and date. This information is printed under the format of statement 31.

During germination the parameters CLOK, TEMP, M, KL, DWATER, DELMOS, and TWATER are printed hourly in 7F10.5 format.

When seed germination is reached this is printed under the format of statement 52—GERMINATION TIME EQUALS "F5.0."

During the emergence phase of EMERGE, hourly values of TIME, A, DE, EL, KNL, EM, DT, and EP are printed according to the format of statement 34.

PROGRAM SETUP AND EXECUTION

EMERGE is programed in FORTRAN for a CDC 6400 computer.

EMERGE does not use any special system functions that are peculiar to a CDC 6400. Some variable names are seven characters long, which is a greater word length than most other computers allow. The CDC 6400 also permits the "A format" specification to be a maximum of A (10).

The standard code read by a CDC 6400 is BCD. Computers which have EBCDIC as the standard code may not read cards punched with BCD code. Normally, computers can read either code, provided an appropriate control card is utilized.

The card deck is arranged in the following sequence:

A. Control cards
   1. Job card
   2. RUN (S)
   3. SETCORE
   4. LGO

   End-of-record card: Multiple-punch 7-8-9 in card column 1

B. Main program deck

C. Subroutines
End-of-record card: Multiple-punch 7-8-9 in card column 1

D. Data
End-of-file card: Multiple punch 6-7-8-9 in card column 1

The RUN (S) card in the control card section causes the computer to compile EMERGE. All memory locations in the computer are zeroed by the SETCORE card. The LGO card causes the program to be executed. In addition to the initializing accomplished by the LGO card, some variables are initially set equal to zero in the main program. However, for the control cards indicated for running on a CDC 6400, initializing within the main program is redundant. To compile EMERGE requires 10,112 memory locations. Program execution uses 9,984 memory locations. Computer compilation and execution time required to simulate a 10-day emergence period is approximately 5.2 seconds of central processor time.

PROGRAM LISTING

```
              PROGRAM EMERGE(INPUT,OUTPUT,TAPE1=INPUT)

        C******SECTIONS SUBJECT TO CHANGE FOR SIMULATION ARE AS FOLLOWS****

        C******(1)  MOISTURE, BARS-- THIS IS IN A SUBROUTINE
        C******(2)  PHYSICAL IMPEDANCE, PSI

000003        DIMENSION KT(6,4,5), EST(6,4,5)
000003        DIMENSION A(500), DF(500), TIME(500), EL(500),
             1KNL(500), EM(500), FP(500), DT(500)
000003        REAL M,K,KNL,KL
000003        READ70,(((KT(I,J,L),L=1,5),J=1,4),I=1,6)
000030        PRINT 88
000034        READ 70,(((EST(I,J,L),L=1,5),J=1,4),I=1,6)
000061     20 READ 30, PLACE, M, PI, IDATE, DEPTH, GP
000101        PRINT 31, PLACE, M, PI, IDATE
000115      1 PRINT 40
000121     70 FORMAT(5F10.0)
000121     88 FORMAT(2H//)
000121     40 FORMAT(///,5X,*TIME*,6X,*TEMP*,5X,*MOS*,8X,*KL*,6X,
             1*DWATER*,5X,*DELMOS*,3X,*TWATER*/)
000121     50 FORMAT(16F5.0)
000121     51 FORMAT(7F10.5)
000121     52 FORMAT(//10X,*GERMINATION TIME EQUALS*,F5.0,2X,*HOURS*//)
000121     30 FORMAT(A10,F5.0,F5.0,5X,A10,2F5.2)
000121     31 FORMAT(1H1,20X,*LOCATION:*,1X,A10,3X,*MOISTURE:*,F5.2,
             13X,*PHYSICAL IMPEDANCE:*,F5.1,3X,*DATE:*,1X,A10//)
000121        GD= GP/100.

        C**** INITIALIZATION OF PARAMETERS

000123        TWATERL=0.
000124        DWATER=0.
000125        CLOK= 0.
000126        GERMT= 0.
000127        ELONG=0.
000130        CLOK= 0.
000131        DT(J) = 0.
000134        ELST= .05
000136        EL(J)= 0.
000141        ELONG= 0.
000142        PI= 3.3
000143     60 J=0
000144    500 READ 50,(A(I), I= 1,500)
000157        IF(EOF,1)61,500

        C**** THIS SECTION COMPUTES THE 3-MM RADICLE EMERGENCE EVENT
        C**** BY SIMULATING THE IMBIBITIONAL WATER UPTAKE OF COTTON
        C**** SEED.  THE INPUTS ARE HOURLY SOIL TEMPERATURE F, AND
        C**** SOIL MOISTURE IN BARS.

000162     61 J=J+1
000164        CALL MOIST(M, CLOK)
000166        IF(A(J).GT.100.) A(J)= 100.
000175        TEMP=(A(J)-32.)*.55555555
```

PROGRAM LISTING—Continued

```
000203          CLOK= CLOK + 1.
000205          IF(TEMP.LT.15.55555) GO TO 15
000210          IF(TEMP.GE.32.22220) GO TO 89
000213          IF(TEMP.GE.15.55555) GO TO 90
000216       89 KL= -.05171368 + .000149960*(TEMP**2.) + .03433988*M
               1  - .0006448513*(M  **2.) - .0009024209*TEMP*M
000236          GO TO 91
000236       90 KL= .0337762 + .0000855456*TEMP**2. - .00347882*M
000247       91 DWATER=KL*(80.0 - TWATERL)
000253          IF((TEMP.GE.26.66).AND.(TEMP.LT.32.2)) GO TO 63
000265          IF(TEMP.GT.32.2) GO TO 66
000270          IF((TEMP.GT.21.2).AND.(TEMP.LT.26.66)) GO TO 65
000302          IF((TEMP.LE.21.2).AND.(TEMP.GE.15.55)) GO TO 62
000315       62 DELMOS=-.1133196 + .0007052 54*(TEMP**2.) -.00134777 8*
               1M    + .001177446*(M  **2.)
000333          GO TO 64
000333       63 DELMOS= -.6954544 + .001961955*(TEMP**2.) + .0833515*
               1M    + .007626679*(M  **2.) - .006011228*M  *TEMP
000353          GO TO 64
000353       65 DELMOS= -.3583704 + .001383181*(TEMP**2.) -.03509194*
               1M    + .003506748*(M  **2.)
000371          GO TO 64
000371       66 DELMOS= 3.392908 - .00197022*(TEMP**2.) - .3693547*M
               1  + .008647528*(M  **2.) + .007306203*TEMP*M
000411       64 IF(DWATER.LT.DELMOS)GO TO 10
000414          TWATER= TWATERL + DWATER
000416          GO TO 16
000417       15 KL=0.0
000420          DWATER=0.0
000421          DELMOS=0.0
000422          TWATER=TWATERL
000424       16 PRINT 51,CLOK, TEMP, M,   KL, DWATER, DELMOS, TWATER
000446          TWATERL=TWATER
000450          GO TO 61
000450       10 TWATER=TWATERL + DWATER
000452          PRINT 51,CLOK, TEMP, M,   KL, DWATER, DELMOS, TWATER
000474          GERMT= CLOK
000476          PRINT 52, GERMT
000503          DWATER=0.
000504          TWATERL=0.
000505          GO TO 502

        C**** THIS SECTION CALCULATES HYPOCOTYL ELONGATION IN CM
        C**** USING HOURLY INPUTS OF SOIL TEMPERATURE F, SOIL
        C**** MOISTURE IN BARS, AND PHYSICAL IMPEDANCE IN PSI

000506      502 KKK= GERMT
000510          KN= KKK + 1
000512          J= KKK
000513          TIM= J
000514       22 FORMAT(  1X,*TIME*,2X,*TEMPERATURE*,5X,*DF*,9X,
               1*ELONGATION*,13X,*KNL*,12X,*EMAXT*, 6X,*DTIME*, 4X,*EMPERCENT*)
000514       34 FORMAT( 1X,F4.0,5X,F4.0,7X,F5.3,8X,F7.3,10X,F15.10,5X
               1,F5.2,7X,F6.5,3X,F5.1)
000514       73 J= J + 1
000516          TIM= TIM + 1.
```

PROGRAM LISTING—Continued

```
      T= A(J)
      IF(T.GT. 999.) GO TO 501
      IF((T.LT.60.).OR.(T.GT.104.)) GO TO 46

C**** PHYSICAL IMPEDANCE IS INCREASED WHEN AVERAGE HYPOCOTYL LENGTH
C**** EQUALS PLANTING DEPTH.  IN CALIBRATING THE MODEL, IT WAS
C**** FOUND THAT THE FIELD MEASURED PI VALUES EXPRESSED IN PSI SHOULD
C**** BE DIVIDED BY 10.  THE LOWEST PERMISSIBLE PI VALUE IS 3.3.  IN
C**** GENERAL PI VALUES OF 6, 12, AND 20 ARE REPRESENTATIVE OF LIGHT,
C**** MEDIUM, AND SEVERE SOIL PHYSICAL IMPEDANCES.

      IF(FLONG.GE.DEPTH)GO TO 144
      GO TO 145

C$$$$ PI IS DESCRIBED IN STATEMENT 144

  144 IF((TIM.GE.195.).AND.(TIM.LT.243.))PI=6.3-.054*(TIM-195.)
      IF((TIM.GE.243.).AND.(TIM.LT.338.))PI=3.7-.0178*(TIM-243.)
      IF(TIM.GE.338.)PI=4.5
      IF(PI.LT.3.3)PI=3.3
  145 CALL MOIST(M,TIM)
      KNL(J) = K(T,M,PI,KT)
      EM(J) = K(T,M,PI,EST)
      DE(J)= KNL(J)*ELST*(EM(J) - ELST)
      S= (T - 32)*.555555
      IF(S.LT.21.1111) GO TO 74
      IF((S.GE.21.1111).AND.(S.LE.32.2222)) GO TO 75
      IF(S.GT.32.2222) GO TO 92
   74 CON=.202744E-06
      TMAX=492.899 -CON*EXP(S) - 17.6902*M - 1.50139*(M**2)
     1+ 2.76729*M
      GO TO 93
   75 DON=.436166E-12
      TMAX=471.445 - 13.6641*S + DON*EXP(S) + 62.4350*M
     1- 2.35855*(M**2) - .548660*S*M
      GO TO 93
   92 TMAX=82.8845+96.9449*M-2.25039*(M**2)-1.69967*S*M
   93 DT(J)= 1.0/TMAX + DT(J-1)
      IF(EM(J).LT.ELST) GO TO 47
      EL(J)= EL(J-1) + DE(J)

C**** THIS SECTION COMPUTES PERCENTAGE EMERGENCE FROM THE AVERAGE
C**** HYPOCOTYL LENGTH(EL(J))

      IF(FLONG.LT.1.0) GO TO 252

C$$$$ THIS SECTION CALCULATES THE STATEMENT NUMBER OF THE EQUATION
C$$$$ TO BE USED IN CALCULATING PERCENTAGE EMERGENCE. THE CORRECT
C$$$$ EQUATION DEPENDS ON PLANTING DEPTH.

      IF(DEPTH.LT.1.875)GO TO 1000
      IF(DEPTH.GE.6.875)GO TO 1001
      NDEPTH=(DEPTH/1.25) + .5
      GO TO 1002
 1000 NDEPTH=1
      GO TO 1002
```

PROGRAM LISTING—Continued

```
001011     1001 NDEPTH=6
001013     1002 GO TO(200,201,202,203,204,205),NDEPTH

        C      APPLICABLE RANGE OF ELONG IS 1.0 - 4.8 CM.  DEPTH= 1.3 CM
001025     200 EP(J)=48.4553*ELONG - 6.62388*(ELONG**2) + .239116*(ELONG**3) - .8
              126568*ELONG*M
001046         GO TO 250
        C      APPLICABLE RANGE OF ELONG IS 1.0 - 5.6 CM.    DEPTH = 2.5 CM
001047     201 IF((ELONG.LT.1.0).OR.(ELONG.GT.6.7)) GO TO 250
001062         EP(J)=   -22.8372*ELONG + 24.9413*(ELONG**2) - 3.81217*(ELONG**3)
              1+  .0204049*(ELONG**5)
001105         GO TO 250
        C      APPLICABLE RANGE OF ELONG IS 1.0 - 6.6 CM.    DEPTH= 3.8 CM
001106     202 IF((ELONG.LT.1.4).OR.(ELONG.GT.6.6))GO TO 250
001121         EP(J)=  4.34967*M-12.9137*ELONG+7.47138*(ELONG**2)-.0123471*(E
              1LONG**5) - 2.06569*ELONG*M
001144         GO TO 250
        C      APPLICABLE RANGE OF ELONG IS 1.0 - 7.5 CM.    DEPTH= 5.0 CM
001145     203 EP(J)=-11.6959*ELONG + 5.09969*(ELONG**2) - .0354686*(ELONG**4) +
              11.37004*(M**2) - 1.3153*ELONG*M
001173         GO TO 250
        C      APPLICABLE RANGE OF ELONG IS 1.0 - 7.5 CM.   DEPTH= 6.3CM
001174     204 EP(J)=-12.0228*M + 13.1315*ELONG - 8.56872*(ELONG**2) + 1.61419*(E
              1LONG**3) - .00985923*(ELONG**5) + 3.11801*(M**2) + .992038*ELONG*M
001231         GO TO 250
        C      APPLICABLE RANGE OF ELONG IS 2.4 - 7.5 CM.   DEPTH= 7.5 CM
001232     205 IF((ELONG.LT.3.5).OR.(ELONG.GT.7.5)) GO TO 250
001245         EP(J)=-8.48373*M + 5.0013*ELONG - 1.53460*(ELONG**3) + .438285*(EL
              1ONG**4) - .0303805*(ELONG**5) + 2.0752*(M**2) + .813498*ELONG*M
001302     250 EP(J)= EP(J)*GD
001307         IF(EP(J).LT.EP(J-1)) EP(J)= EP(J-1)
001322     252 ELST= DE(J) + ELST
001326         ELONG= EL(J)
001331         TIME(J)= TIM
001334         GO TO 73
001335      46 DE(I)= 0.
001340         KNL(J)= 0.
001343         EM(J)= 0.
001346         TIME(J)= TIM
001351         EL(J)= EL(J-1)
001356         DT(J)= DT(J-1)
001363         EP(J)= EP(J-1)
001370         GO TO 73
001371      47 DE(J)= 0.
001374         TIME(J)= TIM
001377         EL(J)= EL(J-1)
001404         EP(J)= EP(J-1)
001411         GO TO 73
001412     501 PRINT 22
001416         PRINT 34,(TIME(I), A(I), DE(I), EL(I), KNL(I), EM(I), DT(I), EP(I)
              1,I=KN,J)
001457         STOP
001461         END

               SUBROUTINE MOIST(M, TCLOK)

        C**** THE SECTION  BELOW EXPRESSES THE MOISTURE IN THE SEED ZONE AS A
        C**** FUNCTION OF TIME FOR A PARTICULAR FIELD TEST
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```
000006          REAL M
000006          IF(TCLOK.LT.122.)M=.9
000011          IF((TCLOK.GE.122.).AND.(TCLOK.LT.168.))M=.9+.0108*(TCLOK-122.)
000027          IF((TCLOK.GE.168.).AND.(TCLOK.LT.216.))M=1.4
000042          IF((TCLOK.GE.216.).AND.(TCLOK.LT.289.))M=1.4+.0137*(TCLOK-216.)
000060          IF((TCLOK.GE.289.).AND.(TCLOK.LT.338.))M=2.4+.0122*(TCLOK-289.)
000076          IF(TCLOK.GE.338.)M=3.
000102          RETURN
000103          END


                REAL FUNCTION K(T,M,PI,KT)

          C**** THIS FUNCTION CALCULATES THE VALUE OF EMAXT AND KNL FOR HYPOCOTYL
          C**** ELONGATION AS A FUNCTION OF TEMPERATURE F, MOISTURE IN BARS, AND
          C**** PHYSICAL IMPEDANCE IN PSI BY USING LINEAR INTERPOLATION IN TWO OR
          C**** THREE DIMENSIONS

000011          DIMENSION TA(6),MA(4),PIA(5)
000011          DIMENSION KT(6,4,5)
000011          REAL MA,KT,M,KL,KU,KSUB
000011          DATA TA/60.0,70.0,80.0,90.0,100.0,104.0/,MA/0.33,3.0,
               1 10.0,11.0/,PIA/3.3,16.0,32.0,48.0,50.0/
000011          ITL=ITU=0
000013          DO 1 I=1,6
000014          IF(T.GE.TA(I)) GO TO 1
000020          ITL=I-1
000022          ITU=I
000023          GO TO 3
000024        1 CONTINUE
000026        3 DT=(T-TA(ITL))/(TA(ITU)-TA(ITL))
000041          IF(DT.EQ.0.) ITU=ITL
000043          IMU=IML=0
000045          DO 2 I=1,4
000047          IF(M.GE.MA(I)) GO TO 2
000053          IML=I-1
000055          IMU=I
000056          GO TO 4
000057        2 CONTINUE
000061        4 DM=(M-MA(IML))/(MA(IMU)-MA(IML))
000074          IF(DM.EQ.0.) IMU=IML
000076          IPL=IPU=0
000100          DO 5 I=1,5
000102          IF(PI.GE.PIA(I)) GO TO 5
000106          IPL=I-1
000110          IPU=I
000111          GO TO 6
000112        5 CONTINUE
000114        6 DP=(PI-PIA(IPL))/(PIA(IPU)-PIA(IPL))
000127          IF(DP.EQ.0.) IPU=IPL
000131          D=SQRT(DP**2. + DM**2. + DT**2.)
000151          KL=KT(ITL,IML,IPL)
000162          KU=KT(ITU,IMU,IPU)
000171       11 IF((DT.GT.0.).AND.(DM.GT.0.)) GO TO 12
000203          IF((DT.GT.0.).AND.(DP.GT.0.)) GO TO 13

          C     CALCULATION OF K WHEN MOISTURE AND PHYSICAL IMPEDANCE ARE
          C     BETWEEN TABLE VALUES
```

PROGRAM LISTING—Continued

```
000215         9 K=D*(KU-KL) + KL
000222           GO TO 10

        C        CALCULATIONS TO FIND PROPER VALUE OF K WHEN TEMPERATURE AND
        C        MOISTURE ARE BETWEEN TABLE VALUES

000222        12 IF(DP.GT.0.) GO TO 14


000225           DIFML=(MA(IML)-M)/(MA(IML)- MA(IMU))
000240           SUBL1= (DIFML)*(KT(ITL,IML,IPL) - KT(ITL,IMU,IPL))
000255           SUBL2= KT(ITL,IML,IPL) - SUBL1
000265           DIFMU= (MA(IML) - M)/(MA(IML) -MA(IMU))
000300           SUBU1= (DIFMU)*(KT(ITU,IML,IPL) - KT(ITU,IMU,IPL))
000315           SUBU2= KT(ITU,IML,IPL) - SUBU1
000325           KSUB=((SUBU2-SUBL2)*(TA(ITU)-T))/(TA(ITU)-TA(ITL))
000344           K= SUBU2 - KSUB
000346           GO TO 10

        C        CALCULATIONS OF K WHEN TEMPERATURE AND PHYSICAL IMPEDANCE ARE
        C        BETWEEN TABLE VALUES

000346        13 IF(DM.GT.0.) GO TO 14
000351           DIFML=(PIA(IPL)-PI)/(PIA(IPL) - PIA(IPU))
000364           SUBL1= (DIFML)*(KT(ITL,IML,IPL) - KT(ITL,IML,IPU))
000401           SUBL2= KT(ITL,IML,IPL) - SUBL1
000411           DIFMU= (PIA(IPL) - PI)/(PIA(IPL) - PIA(IPU))
000424           SUBU1= (DIFMU)*(KT(ITU,IML,IPL) - KT(ITU,IML,IPU))
000441           SUBU2= KT(ITU,IML,IPL) - SUBU1
000451           KSUB=((SUBU2-SUBL2)*(TA(ITU)-T))/(TA(ITU) - TA(ITL))
000470           K= SUBU2 - KSUB
000472           GO TO 10
000472        15 IF(DT.GT.0.) GO TO 14
000475           DIFML= (MA(IML) - M)/(MA(IML) - MA(IMU))
000510           SUBL1= (DIFML)*(KT(ITL,IML,IPL) - KT(ITL,IMU,IPL))
000525           SUBL2= KT(ITL,IML,IPL) - SUBL1
000535           DIFMU= DIFML
000536           SUBU1= (DIFMU)*(KT(ITL,IML,IPU) - KT(ITL,IMU,IPU))
000553           SUBU2= KT(ITL,IML,IPU) - SUBU1
000563           KSUB= ((SUBU2 - SUBL2)*(PIA(IPU) - PI))/(PIA(IPU) - PIA(IPL))
000602           K= SUBU2 - KSUB
000604           GO TO 10

        C        CALCULATION OF K WHEN TEMPERATURE, MOISTURE, AND PHYSICAL
        C        IMPEDANCE ARE BETWEEN TABLE VALUES

000604        14 DIFSQ= SQRT(DM**2 + DP**2)
000620           SUBL1= DIFSQ*(KT(ITL,IML,IPL)- KT(ITL,IMU,IPU))
000640           SUBL2= KT(ITL,IML,IPL) - SUBL1
000650           SUBU1= DIFSQ*(KT(ITU,IML,IPL) - KT(ITU,IMU,IPU))
000665           SUBU2= KT(ITU,IML,IPL) - SUBU1
000675           KSUB= ((SUBU2 - SUBL2)*(TA(ITU) - T))/(TA(ITU)- TA(ITL))
000714           K= SUBU2 - KSUB
000716        10 RETURN
000720           END
```

EXAMPLE RUN

Input Data

TABLE OF KT VALUES

```
.C0480832 .01C383691.C139927  .C192581
.C08352267.013597265.C162947  .C199945
.C113208  .CC705326           .C1C2575

.C0501412 .013159308.C187783  .C2CC439
.C0469919 .CC920764 .C172229  .C198467
.C113818  .0138237  .C133494

.C0788747 .0128454  .0152562  .C25281C
.C0444414 .C0795C115.C19C638  .C25281C
.C0557594 .0122496  .C226051  .C431408

.C08331856.015699449.C271838  .C485776
.C0C5CCC0 .CC975761 .C198626  .C26354C
.C0651485 .0162866  .C562627

.C0898465 .0149C86  .C330927  .C629105
.C58517C36.0435381
.C0C0CC0  .CCCCC0   .CCC0C0   .CCCCCCC
```

TABLE OF EST VALUES

```
2.75    1.25    .85    .55
1.65     .75    .55    .35
 .75     .25    .15    .25

7.85    3.C5   1.65   1.35
4.95    2.85   1.45    .95
1.15     .75    .35    .15

8.25    3.55   2.35   1.55
6.25    3.5C   1.55   1.05
2.95     .65    .35    .25

9.85    4.15   2.25   1.25
7.55    2.95   1.55    .65
3.55    1.C5    .35

7.05    2.75   1.55    .75
 .45     .25
0.0C    0.CC   C.CC   C.CC
```

PLACE M PI IDATE DEPTH GP

```
LUBBOCK      1.0  3.3     4-28-71     5.0089.00
```

SEED-LEVEL TEMPERATURES

69	68	69	69	69	68	67	65	64	62	61	60	59	58	57	56
55	54	54	55	58	62	68	72	75	78	79	79	78	76	74	71
69	67	66	65	64	63	62	62	61	61	61	61	65	68	72	75
80	83	84	84	82	81	78	74	72	71	69	67	67	65	63	63
61	60	60	62	63	67	71	74	76	79	80	80	79	78	76	74
72	70	68	67	66	64	64	62	61	61	61	62	65	68	74	76
80	82	83	83	82	81	78	76	74	73	71	70	69	68	67	66
65	64	63	64	65	68	71	74	76	79	80	81	80	79	77	75
73	72	71	70	69	68	67	66	65	65	65	66	68	70	74	77
79	80	80	80	79	78	77	76	75	74	73	72	71	69	68	66
64	63	63	64	66	68	72	75	77	79	80	80	79	78	76	74
73	71	69	68	66	65	64	63	62	61	61	63	66	67	71	76
79	81	82	80	79	78	77	74	72	70	70	68	67	65	65	64
64	63	63	64	66	68	71	76	78	82	84	84	84	82	80	77
75	73	71	70	69	68	67	66	65	65	64	65	65	66	67	68
71	73	73	73	72	71	69	68	67	66	66	65	65	65	65	65
65	65	66	67	69	72	71	77	79	80	81	80	79	77	75	72
71	68	67	67	64	63	63	62	61	61	63	66	68	72	74	80
81	82	83	82	81	79	76	73	73	73	71	70	69	68	67	66
65	64	64	64	66	68	70	72	73	73	74	75	73	73	71	69
68	68	66	65	64	63	62	62	61	60	60	61	63	65	67	69
72	74	76	76	76	76	74	73	69	66	65	63	62	60	58	57
57	55	54	54	57	63	65	70	74	77	80	81	82	81	79	76
74	71	69	68	66	65	63	62	60	60	58	59	60	65	69	71
76	79	80	81	81	79	78	74	72	71	70	68	67	66	66	65

9999.

Output Data

LOCATION: LUBBOCK MOISTURE: 1.00 PHYSICAL IMPEDANCE: 3.3 DATE: 4-28-71

TIME	TEMP	MOS	KL	DWATER	DELMOS	TWATER
1.00000	20.55556	.90000	.06679	5.34327	.18441	5.34327
2.00000	20.00000	.90000	.06486	4.84250	.16852	10.18577
3.00000	20.55556	.90000	.06679	4.66296	.18441	14.84873
4.00000	20.55556	.90000	.06679	4.35151	.18441	19.20024
5.00000	20.55556	.90000	.06679	4.06087	.18441	23.26111
6.00000	20.00000	.90000	.06486	3.68028	.16852	26.94139
7.00000	19.44444	.90000	.06299	3.34210	.15307	30.28350
8.00000	18.33333	.90000	.05940	2.95307	.12346	33.23656
9.00000	17.77778	.90000	.05768	2.69740	.10932	35.93397
10.00000	16.66667	.90000	.05441	2.39754	.08233	38.33151
11.00000	16.11111	.90000	.05285	2.20219	.06948	40.53369
12.00000	15.55556	.90000	.05135	2.02640	.05708	42.56010
13.00000	15.00000	.90000	0.00000	0.00000	0.00000	42.56010
14.00000	14.44444	.90000	0.00000	0.00000	0.00000	42.56010
15.00000	13.88889	.90000	0.00000	0.00000	0.00000	42.56010
16.00000	13.33333	.90000	0.00000	0.00000	0.00000	42.56010
17.00000	12.77778	.90000	0.00000	0.00000	0.00000	42.56010
18.00000	12.22222	.90000	0.00000	0.00000	0.00000	42.56010
19.00000	12.22222	.90000	0.00000	0.00000	0.00000	42.56010
20.00000	12.77778	.90000	0.00000	0.00000	0.00000	42.56010
21.00000	14.44444	.90000	0.00000	0.00000	0.00000	42.56010
22.00000	16.66667	.90000	.05441	2.03703	.08233	44.59713
23.00000	20.00000	.90000	.06486	2.29635	.16852	46.89348
24.00000	22.22222	.90000	.07289	2.41313	.29594	49.30661
25.00000	23.88889	.90000	.07946	2.43903	.40224	51.74564
26.00000	25.55556	.90000	.08651	2.44440	.51622	54.19004
27.00000	26.11111	.90000	.08897	2.29630	.55593	56.48634
28.00000	26.11111	.90000	.08897	2.09200	.55593	58.57833
29.00000	25.55556	.90000	.08651	1.85327	.51622	60.43161
30.00000	24.44444	.90000	.08176	1.59994	.43938	62.03155
31.00000	23.33333	.90000	.07722	1.38753	.36595	63.41907
32.00000	21.66667	.90000	.07080	1.17400	.26221	64.59307
33.00000	20.55556	.90000	.06679	1.02904	.18441	65.62211
34.00000	19.44444	.90000	.06299	.90565	.15307	66.52776
35.00000	18.88889	.90000	.06117	.82406	.13805	67.35182
36.00000	18.33333	.90000	.05940	.75128	.12346	68.10310
37.00000	17.77778	.90000	.05768	.68624	.10932	68.78933
38.00000	17.22222	.90000	.05602	.62800	.09560	69.41734
39.00000	16.66667	.90000	.05441	.57578	.08233	69.99312
40.00000	16.66667	.90000	.05441	.54445	.08233	70.53757
41.00000	16.11111	.90000	.05285	.50009	.06948	71.03766
42.00000	16.11111	.90000	.05285	.47366	.06948	71.51132
43.00000	16.11111	.90000	.05285	.44863	.06948	71.95995
44.00000	16.11111	.90000	.05285	.42492	.06948	72.38487
45.00000	18.33333	.90000	.05940	.45232	.12346	72.83719
46.00000	20.00000	.90000	.06486	.46460	.16852	73.30180
47.00000	22.22222	.90000	.07289	.48823	.29594	73.79003
48.00000	23.88889	.90000	.07946	.49347	.40224	74.28350
49.00000	26.66667	.90000	.09148	.52293	.62704	74.80643

GERMINATION TIME EQUALS 49 HOURS

Output Data—Continued

TIME	TEMP	DE	ELONGATION	KNL	EMAXT	DTIME	EMPERCENT
50	83	.003	.003	.0070046300	8.28	.00797	0.0
51	84	.003	.006	.0069553809	8.44	.01643	0.0
52	84	.003	.009	.0069553809	8.44	.02488	0.0
53	82	.003	.013	.0070538790	8.13	.03240	0.0
54	81	.004	.016	.0071031280	7.98	.03952	0.0
55	78	.003	.020	.0067112792	7.70	.04561	0.0
56	74	.003	.023	.0058290835	7.47	.05073	0.0
57	72	.003	.025	.0053879856	7.35	.05547	0.0
58	71	.003	.028	.0051674367	7.29	.06004	0.0
59	69	.003	.031	.0050086883	6.76	.06330	0.0
60	67	.002	.033	.0051322893	5.82	.06567	0.0
61	67	.002	.036	.0051322893	5.82	.06804	0.0
62	65	.002	.038	.0052558904	4.87	.07022	0.0
63	63	.002	.040	.0053794914	3.93	.07234	0.0
64	63	.002	.041	.0053794914	3.93	.07446	0.0
65	61	.001	.043	.0055030924	2.99	.07656	0.0
66	60	.001	.044	.0055648930	2.52	.07866	0.0
67	60	.001	.045	.0055648930	2.52	.08076	0.0
68	62	.002	.047	.0054412919	3.46	.08286	0.0
69	63	.002	.049	.0053794914	3.93	.08498	0.0
70	67	.003	.052	.0051322893	5.82	.08735	0.0
71	71	.004	.056	.0051674367	7.29	.09192	0.0
72	74	.005	.060	.0058290835	7.47	.09704	0.0
73	76	.005	.066	.0062701813	7.59	.10261	0.0
74	79	.006	.072	.0069318281	7.76	.10901	0.0
75	80	.007	.078	.0071523771	7.82	.11575	0.0
76	80	.007	.085	.0071523771	7.82	.12249	0.0
77	79	.007	.093	.0069318281	7.76	.12890	0.0
78	78	.007	.100	.0067112792	7.70	.13500	0.0
79	76	.007	.107	.0062701813	7.59	.14056	0.0
80	74	.007	.114	.0058290835	7.47	.14568	0.0
81	72	.006	.120	.0053879856	7.35	.15042	0.0
82	70	.006	.126	.0049468878	7.23	.15600	0.0
83	68	.005	.131	.0050704888	6.29	.15863	0.0
84	67	.005	.136	.0051322893	5.82	.16100	0.0
85	66	.005	.141	.0051940898	5.34	.16325	0.0
86	64	.004	.146	.0053176909	4.40	.16539	0.0
87	64	.004	.150	.0053176909	4.40	.16753	0.0
88	62	.004	.154	.0054412919	3.46	.16964	0.0
89	61	.003	.157	.0055030924	2.99	.17174	0.0
90	61	.003	.160	.0055030924	2.99	.17384	0.0
91	61	.003	.163	.0055030924	2.99	.17594	0.0
92	62	.004	.167	.0054412919	3.46	.17805	0.0
93	65	.005	.172	.0052558904	4.87	.18022	0.0
94	68	.007	.179	.0050704888	6.29	.18286	0.0
95	74	.010	.189	.0058290835	7.47	.18798	0.0
96	76	.011	.200	.0062701813	7.59	.19354	0.0
97	80	.014	.213	.0071523771	7.82	.20028	0.0
98	82	.015	.228	.0070538790	8.13	.20781	0.0
99	83	.016	.243	.0070046300	8.28	.21578	0.0
100	83	.016	.260	.0070046300	8.28	.22375	0.0
101	82	.017	.277	.0070538790	8.13	.23127	0.0
102	81	.018	.295	.0071031280	7.98	.23838	0.0
103	78	.017	.312	.0067112792	7.70	.24448	0.0

Output Data—Continued

104	76	.016	.328	.0062701813	7.59	.25004	0.0
105	74	.016	.344	.0058290835	7.47	.25516	0.0
106	73	.015	.359	.0056085346	7.41	.26008	0.0
107	71	.015	.374	.0051674367	7.29	.26465	0.0
108	70	.014	.388	.0049468878	7.23	.27023	0.0
109	69	.014	.402	.0050086883	6.76	.27309	0.0
110	68	.013	.415	.0050704888	6.29	.27613	0.0
111	67	.013	.428	.0051322893	5.82	.27850	0.0
112	66	.012	.440	.0051940898	5.34	.28074	0.0
113	65	.011	.452	.0052558904	4.87	.28292	0.0
114	64	.010	.462	.0053176909	4.40	.28506	0.0
115	63	.009	.471	.0053794914	3.93	.28718	0.0
116	64	.011	.482	.0053176909	4.40	.28932	0.0
117	65	.012	.494	.0052558904	4.87	.29150	0.0
118	68	.016	.510	.0050704888	6.29	.29413	0.0
119	71	.019	.530	.0051674367	7.29	.29870	0.0
120	74	.023	.553	.0058290835	7.47	.30382	0.0
121	76	.026	.579	.0062701813	7.59	.30938	0.0
122	79	.031	.610	.0069318281	7.76	.31579	0.0
123	80	.034	.644	.0071384490	7.81	.32251	0.0
124	81	.036	.680	.0070717216	7.96	.32957	0.0
125	80	.037	.716	.0071105928	7.80	.33625	0.0
126	79	.037	.753	.0068811775	7.73	.34258	0.0
127	77	.035	.788	.0064400712	7.60	.34832	0.0
128	75	.033	.822	.0060040266	7.47	.35357	0.0
129	73	.031	.853	.0055730436	7.33	.35841	0.0
130	72	.031	.884	.0053575479	7.26	.36306	0.0
131	71	.030	.914	.0051445830	7.19	.36753	0.0
132	70	.029	.943	.0049341490	7.11	.37317	0.0
133	69	.028	.971	.0050118455	6.64	.37646	0.0
134	68	.027	.998	.0050926638	6.16	.37911	0.0
135	67	.025	1.023	.0051766038	5.69	.38150	0.0
136	66	.023	1.047	.0052636657	5.22	.38375	0.0
137	65	.021	1.068	.0053538493	4.75	.38595	0.0
138	65	.022	1.090	.0053603799	4.74	.38814	0.0
139	65	.022	1.112	.0053669105	4.74	.39033	0.0
140	66	.025	1.137	.0052835445	5.19	.39259	0.0
141	68	.030	1.166	.0051055992	6.09	.39525	0.0
142	70	.035	1.201	.0049214103	7.00	.40096	0.0
143	74	.043	1.244	.0056960368	7.25	.40582	0.0
144	77	.050	1.293	.0062678303	7.44	.41131	0.0
145	79	.056	1.349	.0066405871	7.57	.41730	0.0
146	80	.059	1.408	.0068181032	7.63	.42357	0.0
147	80	.061	1.470	.0068041752	7.62	.42982	0.0
148	80	.063	1.532	.0067902471	7.61	.43606	0.0
149	79	.062	1.595	.0065899364	7.54	.44198	0.0
150	78	.061	1.656	.0063921566	7.46	.44763	0.0
151	77	.060	1.716	.0061969076	7.38	.45302	0.0
152	76	.059	1.774	.0060041895	7.30	.45818	0.0
153	75	.057	1.831	.0058140022	7.22	.46312	0.0
154	74	.056	1.887	.0056263457	7.14	.46786	0.0
155	73	.054	1.941	.0054412201	7.06	.47243	0.0
156	72	.052	1.993	.0052586253	6.98	.47682	0.0
157	71	.050	2.044	.0050785614	6.89	.48105	0.0

Output Data—Continued

158	69	.045	2.088	.0050190210	6.36	.48439	0.0
159	68	.041	2.130	.0051388616	5.91	.48708	0.0
160	66	.033	2.163	.0053829385	5.01	.48936	0.0
161	64	.024	2.187	.0056332590	4.11	.49154	0.0
162	63	.018	2.205	.0057655868	3.66	.49369	0.0
163	63	.018	2.223	.0057752392	3.66	.49585	0.0
164	64	.023	2.247	.0056575335	4.09	.49803	0.0
165	66	.033	2.280	.0054077870	4.97	.50032	0.0
166	68	.042	2.322	.0051517970	5.84	.50301	0.0
167	72	.055	2.378	.0052167735	6.85	.50731	0.0
168	75	.064	2.442	.0056977354	7.07	.51208	0.0
169	77	.071	2.513	.0060216647	7.22	.51725	0.0
170	79	.078	2.591	.0063455941	7.37	.52288	0.0
171	80	.083	2.674	.0065075587	7.45	.52878	.2
172	80	.084	2.757	.0065075587	7.45	.53468	1.0
173	79	.081	2.839	.0063455941	7.37	.54031	1.9
174	78	.079	2.917	.0061836294	7.30	.54571	2.7
175	76	.073	2.990	.0058597001	7.14	.55067	3.6
176	74	.067	3.056	.0055357707	6.99	.55527	4.4
177	73	.064	3.120	.0053738061	6.92	.55970	5.2
178	71	.058	3.178	.0050498768	6.76	.56384	6.0
179	69	.049	3.227	.0050219762	6.25	.56721	6.7
180	68	.043	3.269	.0051560404	5.81	.56990	7.3
181	66	.029	3.299	.0054241686	4.94	.57220	7.9
182	65	.021	3.320	.0055582328	4.50	.57442	8.3
183	64	.013	3.333	.0056922969	4.06	.57660	8.6
184	63	.005	3.338	.0058263610	3.62	.57876	8.8
185	62	0.000	3.338	.0059604252	3.18	.58091	8.8
186	61	0.000	3.338	.0060944893	2.75	.58305	8.8
187	61	0.000	3.338	.0060944893	2.75	.58520	8.8
188	63	.005	3.343	.0058263610	3.62	.58736	8.8
189	66	.028	3.371	.0054241686	4.94	.58965	8.9
190	67	.035	3.406	.0052901045	5.37	.59207	9.3
191	71	.058	3.464	.0050498768	6.76	.59621	9.8
192	76	.075	3.539	.0058597001	7.14	.60118	10.6
193	79	.086	3.625	.0063455941	7.37	.60681	11.6
194	81	.092	3.717	.0063761276	7.60	.61300	12.9
195	82	.094	3.810	.0062446964	7.74	.61950	14.3
196	80	.090	3.901	.0065075587	7.45	.62540	15.7
197	79	.086	3.986	.0063455941	7.37	.63103	17.1
198	78	.081	4.068	.0061836294	7.30	.63642	18.5
199	77	.077	4.145	.0060216647	7.22	.64159	19.8
200	74	.065	4.210	.0055357707	6.99	.64619	21.1
201	72	.057	4.267	.0052118414	6.84	.65047	22.2
202	70	.050	4.317	.0048879121	6.69	.65636	23.2
203	70	.050	4.366	.0048879121	6.69	.66224	24.0
204	68	.032	4.398	.0051560404	5.81	.66494	24.8
205	67	.022	4.420	.0052901045	5.37	.66737	25.4
206	65	.001	4.421	.0055582328	4.50	.66959	25.8
207	65	.001	4.421	.0055582328	4.50	.67181	25.8
208	64	0.000	4.421	.0056922969	4.06	.67399	25.8
209	64	0.000	4.421	.0056922969	4.06	.67617	25.8
210	63	0.000	4.421	.0058263610	3.62	.67834	25.8
211	63	0.000	4.421	.0058263610	3.62	.68050	25.8

PART 4.–SIMCOT II: A SIMULATION OF COTTON GROWTH AND YIELD[1]

By J. M. McKinion, D. N. Baker, J. D. Hesketh, and James W. Jones[2]

INTRODUCTION

On the following pages we document a segment of our work in the simulation of cotton growth and yield and provide operating instructions for the resultant computer model SIMCOT II.

This work began as an effort to assess the theoretical yield limits in commercial upland cottons through the calculations of photosynthate production and respiratory losses (*2, 3*)[3] and evolved into an analysis of the physiological reasons for the failure of these cottons to attain this potential. Stapleton (*7*) and Stapleton and Meyers (*9*) had called for the application of systems methodology to this problem for the purpose of design and optimization of machinery arrays, and this work resulted in the first digital-computer simulation of cotton growth (*8*). Similar work was begun independently and at about the same time by A. B. Hearn (*4*) in Uganda.[4]

SIMCOT II is a direct descendent of SIMCOT, which was developed by Duncan (*5*). The overall approach is the same: the calculation of daily production and distribution of photosynthate. The model continues the same philosophy of fruiting, the triggering of abscission of fruit, and delays in node formation in response to physiological stress in the form of carbohydrate shortage, and it continues to limit above-ground vegetative growth relative to root growth in response to moisture stress. Development is still programed in physiological time (a function of temperature).

There are, however, a number of fundamental changes. A plant-map subroutine has been added, which keeps track of the age, weight, and nutritional status of fruit at every node. This provides an interface of insect damage routines. A nitrogen-balance subroutine has been added. Light interception is based on plant height rather than leaf-area index. Height is a useful index of the overall foliage display and is not density dependent as is leaf-area index.

The systems analysis has resulted in other basic changes. We have found that carbohydrate reserves are all available on a temporary basis and (now) may approximate 30% of the dry leaf weight. We have found that only squares (about 12 days old) are abscised in response to carbohydrate stress and only squares within a few days of bloom and very small bolls are abscised in response to nitrogen stress. The most fundamental advance of SIMCOT II lies in the abolition of the "standard plant" as a means of calculating potential growth. The logic replacing the standard plant was essential to the simulation and incorporates the notion of senescence of stem and root tissue. This will be described in detail elsewhere. These changes represent new knowledge about the physiology of cotton, which could not have been obtained through classical reductionist experimental research.

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[3] Italic numbers in parentheses refer to items in "Literature Cited," p. 82.

[4] Personal communication, 1970.

VALIDATION

SIMCOT II is essentially a carbohydrate balance. Beginning with emergence, light interception is calculated daily from plant height. From this, photosynthesis is calculated for a unit of ground area. Then, light respiration, maintenance respiration, and growth respiration are calculated and subtracted from photosynthesis to give a net increment of carbohydrate available per plant for growth on that day. Daytime and nighttime increments of growth of roots, stems, leaves, and fruit are calculated separately. The decision as to whether or not to grow leaf and stem tissue is based on estimated plant water stress. All potential growth is based on temperature.

Leaf weights were obtained weekly from large samples of plants grown in State College, Miss., in 1969. From these data a table of daily weight increments was constructed. A drought early in 1969 caused abnormally small leaves. Therefore, to obtain the potential (well-watered) leaf increments needed by SIMCOT II, we multiplied the 1969 data by a factor (LEFADD) to obtain reasonable leaf weights in the simulations (table 4–1). The system's temporary carbohydrate storage capacity is equal to 30% of the leaf weight. Maximum carryover time is 1 day. Leaf senescence is simulated by subtracting from the leaf weight the increment added 70 days previously.

TABLE 4–1.—*Factors to be used to adjust leaf area production*

Plant population	LAFADD
20,498	1.75
41,000	1.35
80,000	1.00
125,000	1.00

Stem growth was developed as follows: Stem weights from the 1969 weekly plant samples were used to provide potential stem weight increments for the first 42 days of growth. From day 10 to day 42 the growth data fit the following expression:

$$\Delta W = 0.2 + 0.06\,(STMWT), \qquad (4\text{–}1)$$

where ΔW is the potential stem growth and $STMWT$ is the accumulated stem weight in grams.

After 42 days, potential stem growth was obtained from the expression

$$\Delta W = 0.2 + 0.06\,(STMWT - I_{24}), \qquad (4\text{–}2)$$

where ΔW is change in weight in grams per day, $STMWT$ is stem weight in grams, and I_{24} is stem growth 24 days earlier.

Potential root growth is computed in the same way as stem growth, except that it is only 10% as large and is not affected by moisture stress.

The growth of each fruit is kept track of individually in two-dimensional matrices (one axis representing the main-stem node number and the other axis, the fruiting-branch node number). Temperature effects are accounted for in computing the date of initiation, bloom, and boll opening. Potential weight increments for each fruit are taken from a table of weight increments versus fruit age. The data in that table are taken from fruit grown with an abundant supply of carbohydrates.

The carbohydrate requirements for potential growth of all organs is summed and then divided into the net carbohydrate available. All organ weights are incremented by that fractional amount of their respective potential growth. If the ratio is greater than 1, the excess is stored in temporary reserve. Any excess beyond 30% of leaf weight is assigned to the stem weight and root weight.

When the first square is 6 days from bloom, a term called BOLINC is computed as the ratio of actual to potential fruit growth. If BOLINC is less than 0.85, stresses are said to exist, which cause the squares to abscise and delay the formation of new nodes, as shown in the flow charts below. All fruit within the appropriate age bracket are shed 8 days from the occurrence of the stress.

The Crops

One crop used to verify our simulation was grown in State College, Miss., in 1961 by Bruce and Römkens (*4*). Briefly, the treatment they used was as follows: The cotton variety was a doubled haploid, 'Deltapine M8948'. Before planting, fertilizer was broadcast at the rates of 75 lb N, 44 lb P, and 83 lb K per acre. Three sidedressings of 75 lb N each were applied at 4-week intervals after planting. The plants emerged on

May 9 and were uniformly spaced in 91-cm rows at 20,498 plants per acre. The soil was irrigated to field capacity whenever tensiometer readings reached 0.3 bar. Insect control was nearly complete. Ten plants were mapped weekly, and the status of the fruit at each node was recorded. We summarized those data to produce weekly maps of an average or representative plant.

Another crop grown commercially and described by Jenkins et al. (*6*) was planted in 101.6-cm rows at 41,000 plants per acre in 1972 in Copiah County, Miss. At planting, fertilizer was banded at the rates of 20 lb N, 17.5 lb P, and 33 lb K per acre. Some moisture stresses were allowed to occur during the season. Again, insect control was very good. Square and boll counts were made weekly on 30 meters of row.

Results

More detail on these validation experiments can be found in papers by Baker et al. (*1*) and by Jenkins et al (*6*). Main-stem node number and fruiting site production in the 1961 crop are presented in figure 4–1. The data describe a typical sigmoid growth curve. Growth is exponential at first, becoming linear as maintenance respiration becomes significant and leveling off somewhat as carbohydrate shortages brought on by the high demands for boll growth delay the formation of new nodes.

Real and simulated fruit production is presented in figure 4–2. To track square production this well early in the season, the model was programed to abscise pinhead squares (1 day old) in response to solar radiation levels above 700 ly/day. The carbohydrate stresses are mild at first, becoming more severe as the season progresses until some of the bolls mature and open around September 14. Day-to-day variation in the stress was caused by variations in the weather (mainly solar radiation).

Two points should be mentioned here concerning the development of this simulation: First, in order to track properly the early onset of stresses (as evidenced by square shedding and a leveling off of site production in the real system), we had to acknowledge the existence of a large vegetative sink. Numerous mechanisms were tried and coefficients used before we developed equation 4–2. This equation states that potential stem growth is proportional to the weight of the vegetative sink and that tissue no longer contributes to sink strength (capable of cell wall thickening) after 24 days. The second point is that all earlier (unvalidated) versions of SIMCOT were based on the assumption that the fruit is most likely to abscise in response to stress at bloom (about 26 days) and that progressively greater stresses would bracket that, with wider and wider age envelopes of fruit abscised. To accomplish this simulation, we were forced to abandon that assumption in favor of abscission at an earlier age (12 days). Depending on stress intensity then, the present model marks squares 8 to 13 days old, and they are 16 to 21 days old at abscission. Abscission of any bolls ruins the simulation. We believe, therefore, that boll shed results from nitrogen stress.

Figure 4–2 shows apparent regrowth (squares) on the 140th day. We had stopped mapping the real plants before that time, so no data are available to verify this. The model predicts regrowth because the maturing of some bolls made additional photosynthate available for development of new meristems.

The model crop reached a maximum leaf-area index (LAI) of 4.2 on day 95 (August 12) and yielded 2.98 bales per acre.

The computer output for the 1972 Copiah County crop is presented under "Example Runs." This simulation was obtained with the same program as above. The real plants, on the average, and the model plants both produced seven bolls for a yield of 1.68 bales per acre. Again, fruiting was simulated almost perfectly. This crop abscised eight young bolls in response to nitrogen stresses.

We feel that this is a minimal validation effort. SIMCOT II obviously simulates Delta cottons well in the Midsouth. We expect that it will do well in the Southeast and in much of Texas. At present certain modifications are necessary for use on the Texas High Plains and in dryland areas. Generally, these modifications are simple to make and should be considered in the following order:

1. Make sure that the algorithms in PNET for computing plant height and light interception are performing properly for your crop. This has required modification for "okra leafed" cottons and for High Plains varieties.

2. Be sure first square occurs on the proper date. For the High Plains varieties a different

number of physiological days to first square must be used.

3. The WATERZ subroutine is simple. Under dryland conditions modifications in selecting plant water stress levels may be needed.

Weaknesses in the simulation in these areas have pointed to potentially productive future experiments. As new information becomes available, we (and we hope others) will make appropriate modifications in the model.

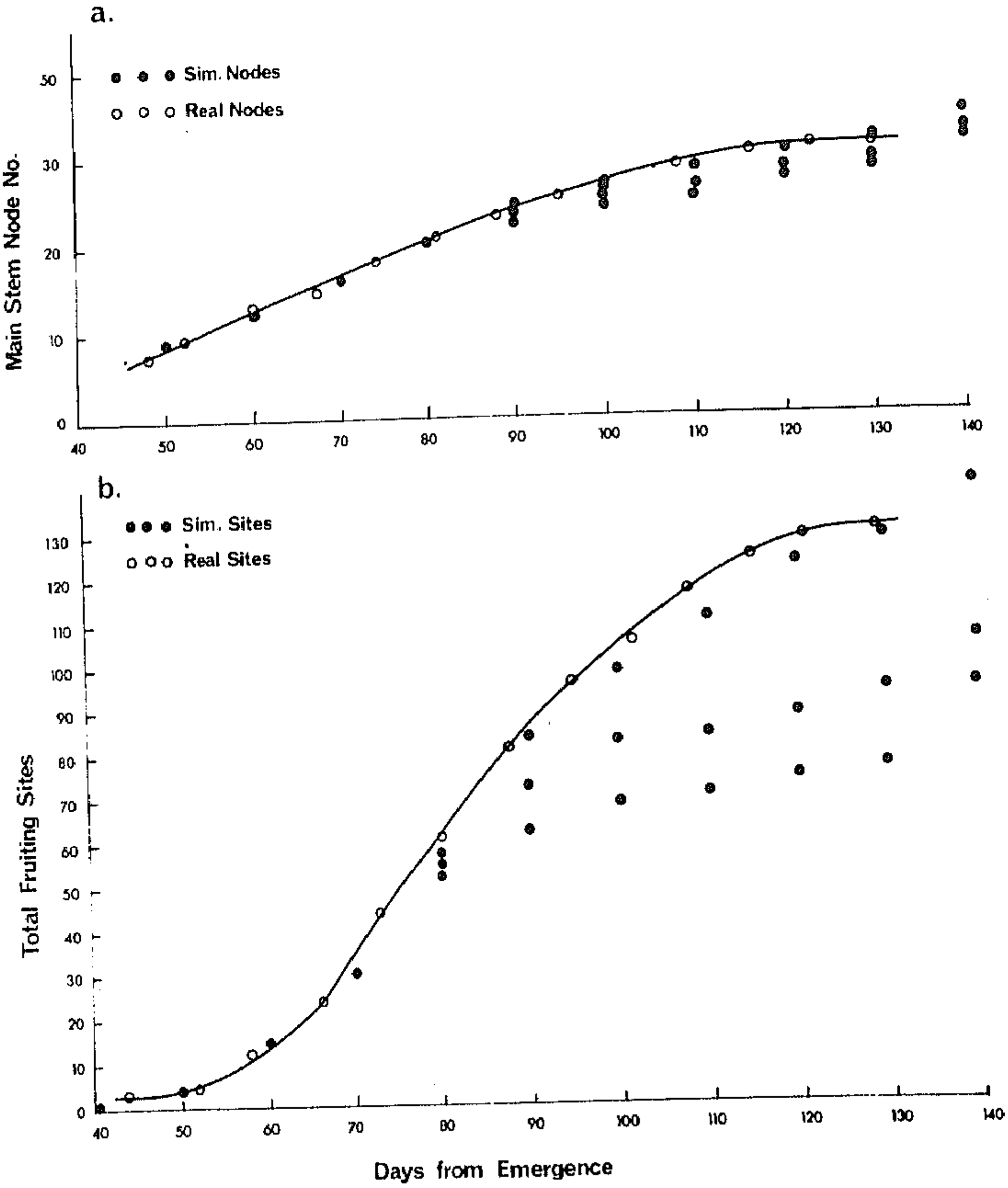


FIGURE 4-1.—A season's time course of main-stem node and fruiting site development. Open circles and lines trace the real crop planted at 20.498 plants per acre. Upper, middle, and lower solid circles represent model predictions for 20,498, 41,000, and 80,000 plants per acre, respectively.

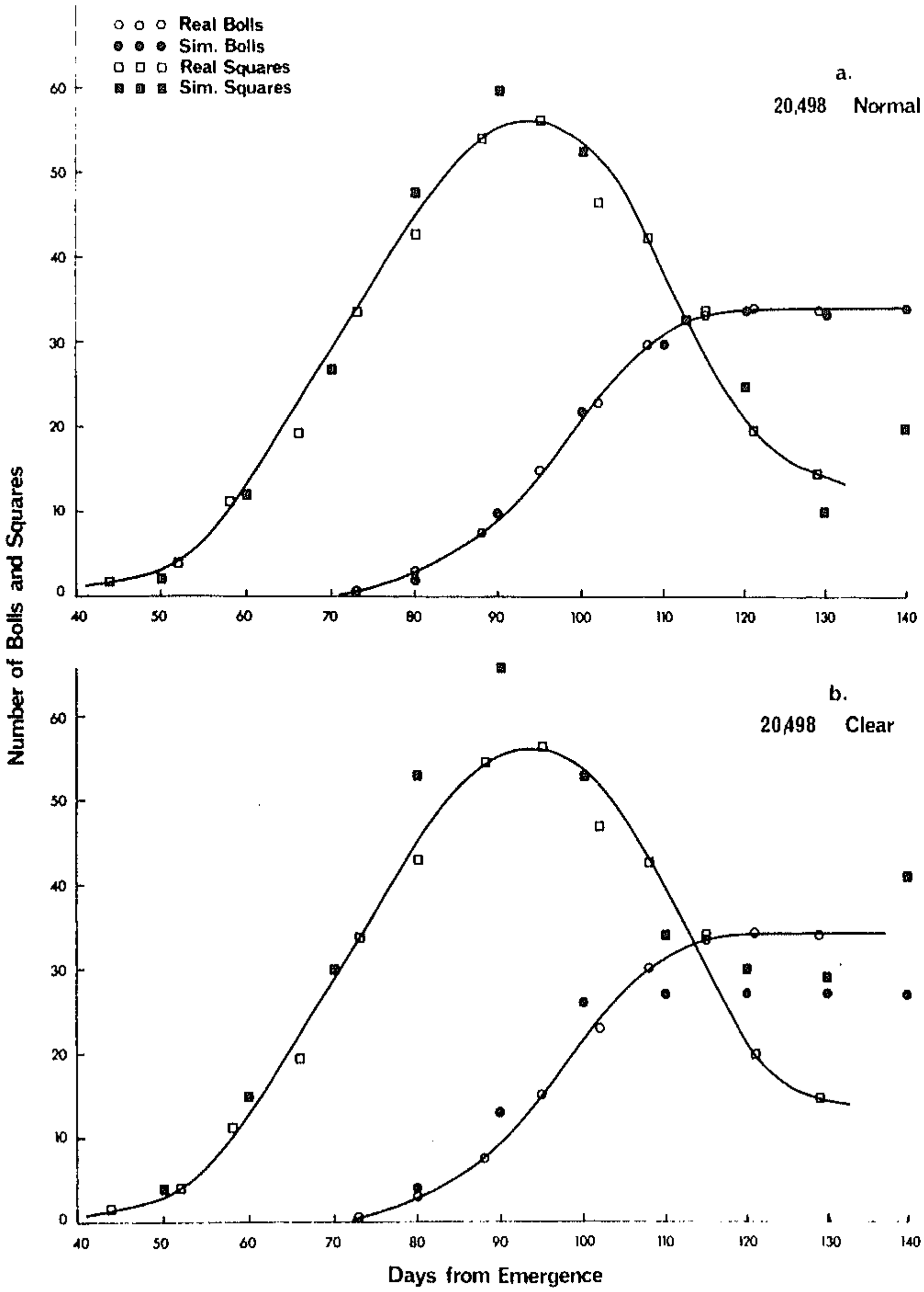
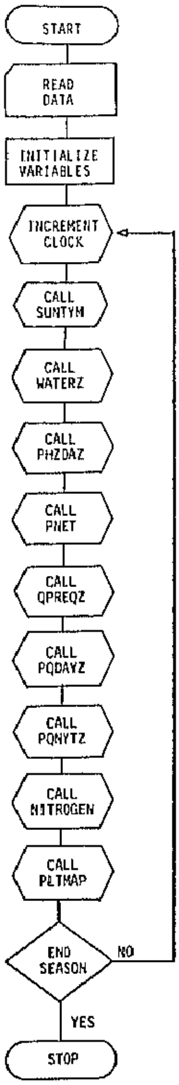


FIGURE 4–2.—Seasonal time course of fruiting for the real crop and for simulated crops at 20,498 plants per acre under normal and all clear skies.

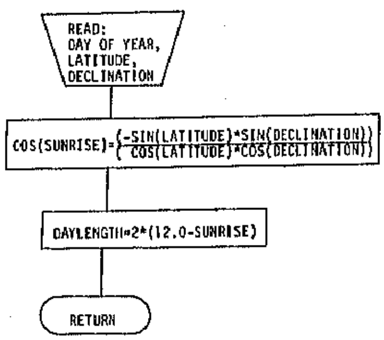
DESCRIPTION AND FLOW CHARTS

M A I N   P R O G R A M



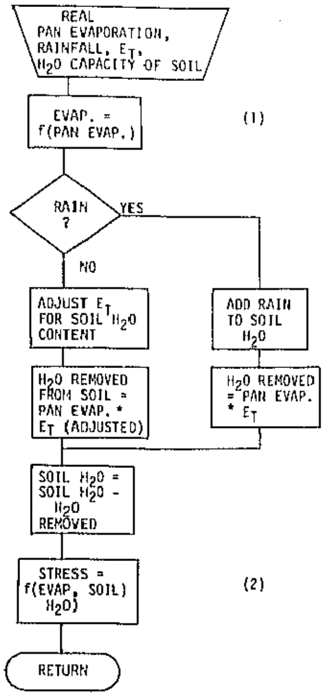
THE MAIN PROGRAM INITIALIZES ALL VARIABLES, READS IN WEATHER DATA, PLANT MANAGEMENT DATA AND CALLS ALL SUBROUTINES TO GROW THE PLANT. AFTER THE PLANT HAS BEEN GROWN TO THE END OF THE SEASON, THE MAIN PROGRAM THEN PRINTS PERTINENT INFORMATION: SUCH AS, BALES PER ACRE, NUMBER OF OPEN BOLLS. THE USER CAN CAUSE THE PROGRAM TO LIST THE PLANT MAP AS OFTEN AS DESIRED OR NOT AT ALL. IF THE USER DESIRES, HE CAN ALSO MAKE CHANGES IN THE FRUIT MATRIX TO SIMULATE INSECT DAMAGE.

S U B R O U T I N E   S U N T Y M



THIS PROGRAM COMPUTES THE LENGTH OF THE DAY FOR ANY DAY OF THE YEAR.

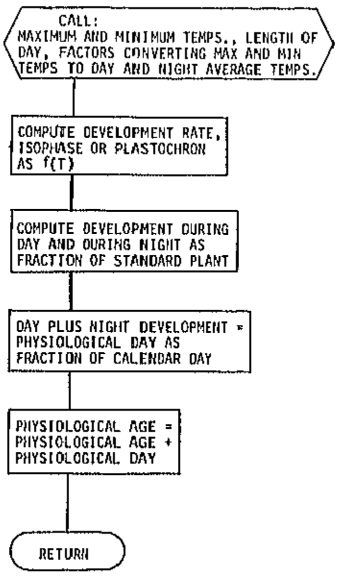
S U B R O U T I N E   W A T E R Z



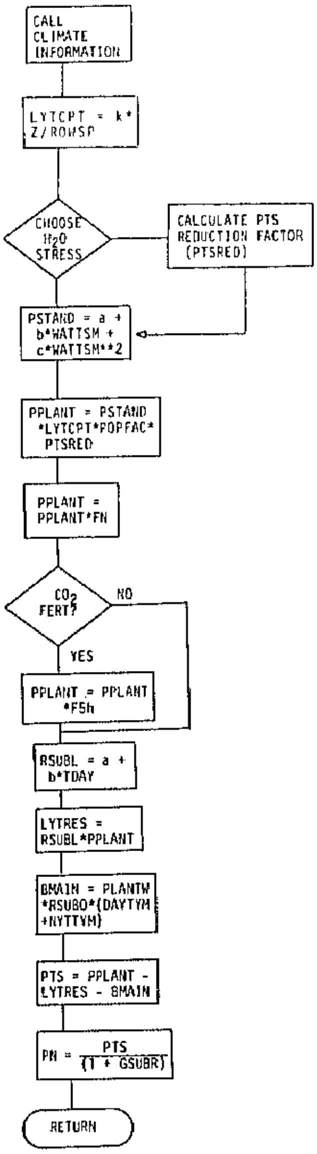
THIS PROGRAM ADJUSTS SOIL MOISTURE FOR EVAPORATION AND RAINFALL AND EVALUATES PLANT STRESS IN TERMS OF WATER REMAINING IN THE SOIL AND THE PAN EVAPORATION FOR THE DAY, ARBITRARILY. CLIMAT (JJ,4) IS RAINFALL AND CLIMAT (JJ,5) IS PAN EVAPORATION FOR THE JJTH DAY. RUNOFF (OR SOAKTHROUGH) IS CALCULATED. MOISTURE STRESS IS CALCULATED FROM THE COMBINATION OF SOIL WATER CONTENT AND EVAPORATIVE DEMAND AS MEASURED BY PAN EVAPORATION.

(1) AND (2) ARE ARBITRARY RELATIONSHIPS.

S U B R O U T I N E   P H Z O A Z

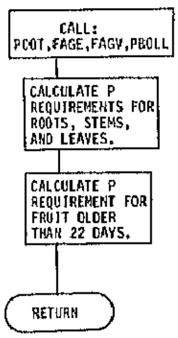


THIS PROGRAM CALCULATES THE LENGTH OF EACH PHYSIOLOGICAL DAY AND NIGHT BASED ON THE ESTIMATED AVERAGE TEMPERATURE OF EACH IN °C. One PHYSIOLOGICAL DAY IS A 24 HOUR PERIOD IN WHICH THE AVERAGE TEMPERATURE WAS 26°C. IF THE AVERAGE TEMPERATURE WAS LESS THAN 26°C, THEN WE HAVE A FRACTION OF A PHYSIOLOGICAL DAY. IF THE AVERAGE TEMPERATURE IS GREATER THAN 26°C, THEN WE HAVE A PHYSIOLOGICAL DAY PLUS A FRACTION.



S U B R O U T I N E P N E T

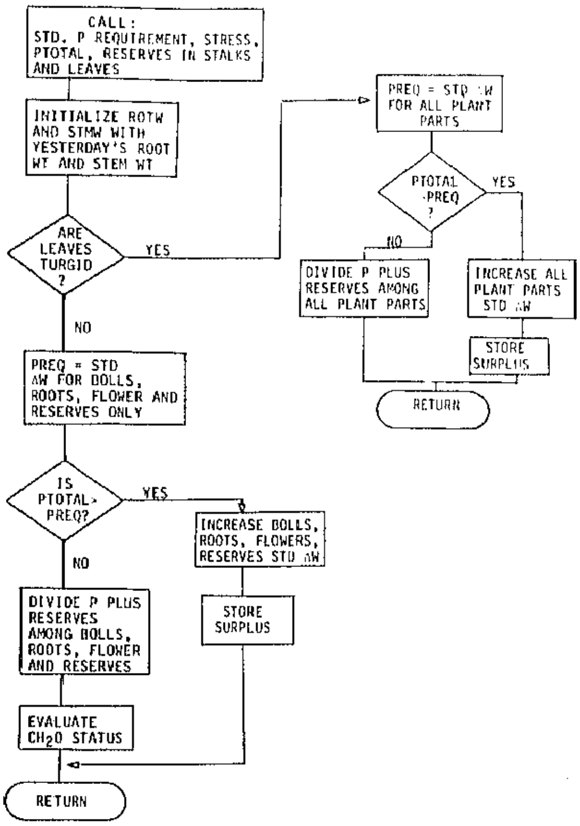
THIS SUBROUTINE CALCULATES THE DAY'S INCREMENT OF NET PHOTOSYNTHATE PRODUCTION PER PLANT. THE FRACTION OF INCIDENT LIGHT INTERCEPTED (LYTCPT) BY THE PLANT CANOPY IS COMPUTED FROM EMPIRICAL DATA BASED ON PLANT HEIGHT (Z). PTSRED IS THE FACTOR BY WHICH LEAF WILTING REDUCES THE RATE OF PHOTOSYNTHESIS. PSTAND IS POTENTIAL GROSS PHOTOSYNTHATE PRODUCTION BY THE PLANT CANOPY BASED ON DAILY TOTAL SOLAR RADIATION (WATTSM). THE POTENTIAL DAY'S GROSS PHOTOSYNTHATE PRODUCTION (PSTAND) IS REDUCED BY THE WATER STRESS FACTOR (PTSRED) AND BY LYTCPT AND FINALLY BY A PLANT POPULATION FACTOR (POPFAC) TO GIVE PHOTOSYNTHATE PRODUCTION ON A PER PLANT BASIS (PPLANT). THIS IS BASED ON EXPERIMENTS IN INTACT CANOPIES AT 300 PPM CO_2. PPLANT IS THEN ADJUSTED FOR AN AVERAGE DAILY CO_2 LEVEL ABOVE 300 IN FIELD AIR. A PROVISION IS MADE FOR FURTHER ADJUSTMENT TO ACCOUNT FOR THE EFFECTS OF CO_2 FERTILIZATION ASSUMING A RELEASE OF 200 LB/ACRE/HR FOR FIVE MIDDAY HOURS. LIGHT RESPIRATION (LYTRES) IS A FUNCTION OF TEMPERATURE AND PROPORTIONAL TO PHOTOSYNTHATE PRODUCTION. MAINTENANCE RESPIRATION IS PROPORTIONAL TO PLANT WEIGHT. GSUBR IS GROWTH RESPIRATION.



S U B R O U T I N E Q P R E Q Z

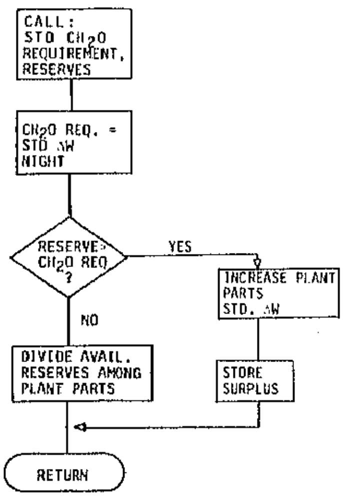
THIS SUBROUTINE CALCULATES THE REQUIRED PHOTOSYNTHATE FOR GROWTH OF EACH PLANT PART: ROOTS, STEMS, LEAVES, AND INDIVIDUAL FRUIT WHICH ARE OLDER THAN 22 DAYS.

SUBROUTINE PQDAYZ



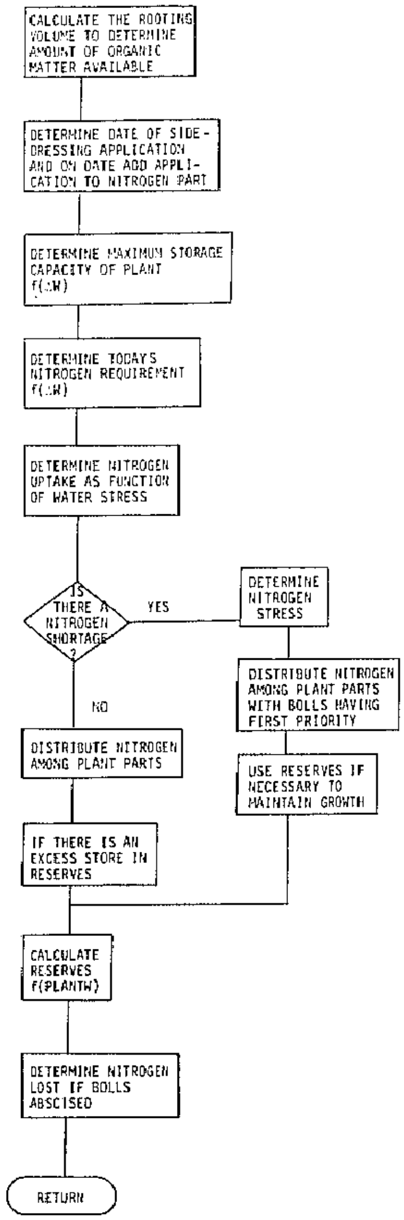
THIS PROGRAM COMPUTES THE PHOTOSYNTHATE USED FOR PLANT GROWTH FOR THE DAY. STMW AND ROTW ARE SET TO TODAYS STEM AND ROOT WEIGHT BEFORE ANY GROWTH OCCURS. THESE TWO VARIABLES ARE THEN USED IN PLTMAP TO RETIRE STEM AND ROOT MATERIAL OLDER THAN 24 DAYS FROM THE RESPIRING BIOMAS. MAXIMUM CH_2O RESERVE SIZE EQUALS 30 PERCENT OF THE LEAF DRY WEIGHT. IT IS ALL AVAILABLE ON ANY GIVEN DAY. PTOTAL = PN + RESERVES. EXCESS PHOTOSYNTHATE BEYOND THAT NEEDED FOR GROWTH AND RESERVES IS ACCUMULATED AS DRY MATTER IN THE ROOTS.

SUBROUTINE PQNYTZ



THIS PROGRAM CALCULATES THE PHOTOSYNTHATE REQUIRED FOR PLANT PARTS FOR THE NIGHT AND COMPUTES THE WEIGHT GAINS EXCEPT FOR FRUIT. IT ALSO COMPUTES WHETHER BOLL SET WILL OCCUR BASED ON THE CALCULATED CARBOHYDRATE STRESS OR LACK OF IT. POLYNA IS THE VARIABLE USED TO DETERMINE BOLL SET AND IT GIVES A VALUE, SIGNALS THAT A BOLL MAY BE SET IF A BLOOM IS PRESENT.

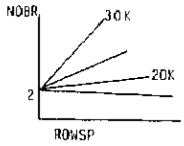
SUBROUTINE NITR



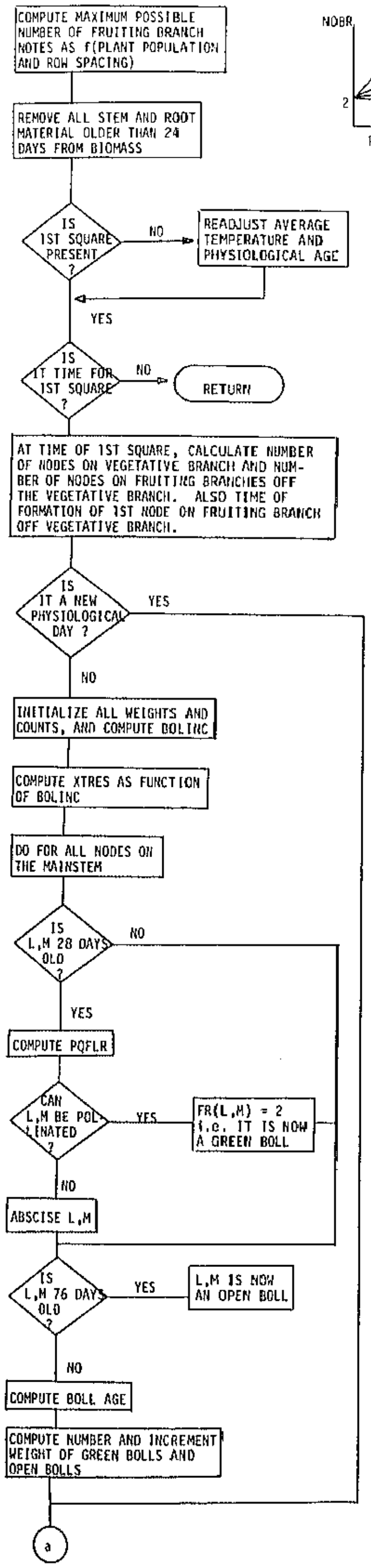
THE NITROGEN SUBROUTINE CALCULATES A NITROGEN BALANCE FOR THE PLANT. NITROGEN REQUIREMENTS FOR STEMS, ROOTS, AND LEAVES ARE CALCULATED AS A FUNCTION OF INCREASE OF WEIGHT OF THE GROWING TISSUES OF THOSE PLANT PARTS. THE SEED AND BURR REQUIREMENTS ARE CALCULATED AS A FUNCTION OF TOTAL FRUIT WEIGHT. NITROGEN UPTAKE IS CALCULATED ON A PLANT BASIS AS A FUNCTION OF WATER STRESS. THIS NITROGEN IS TAKEN FROM A NITROGEN POOL IN THE SOIL THAT CONSISTS OF RESIDUAL NITROGEN FROM THE PREVIOUS YEAR, NITROGEN FROM DECOMPOSITION OF ORGANIC MATTER, AND NITROGEN FROM PRE-EMERGENCE AND SIDEDRESSING APPLICATIONS.

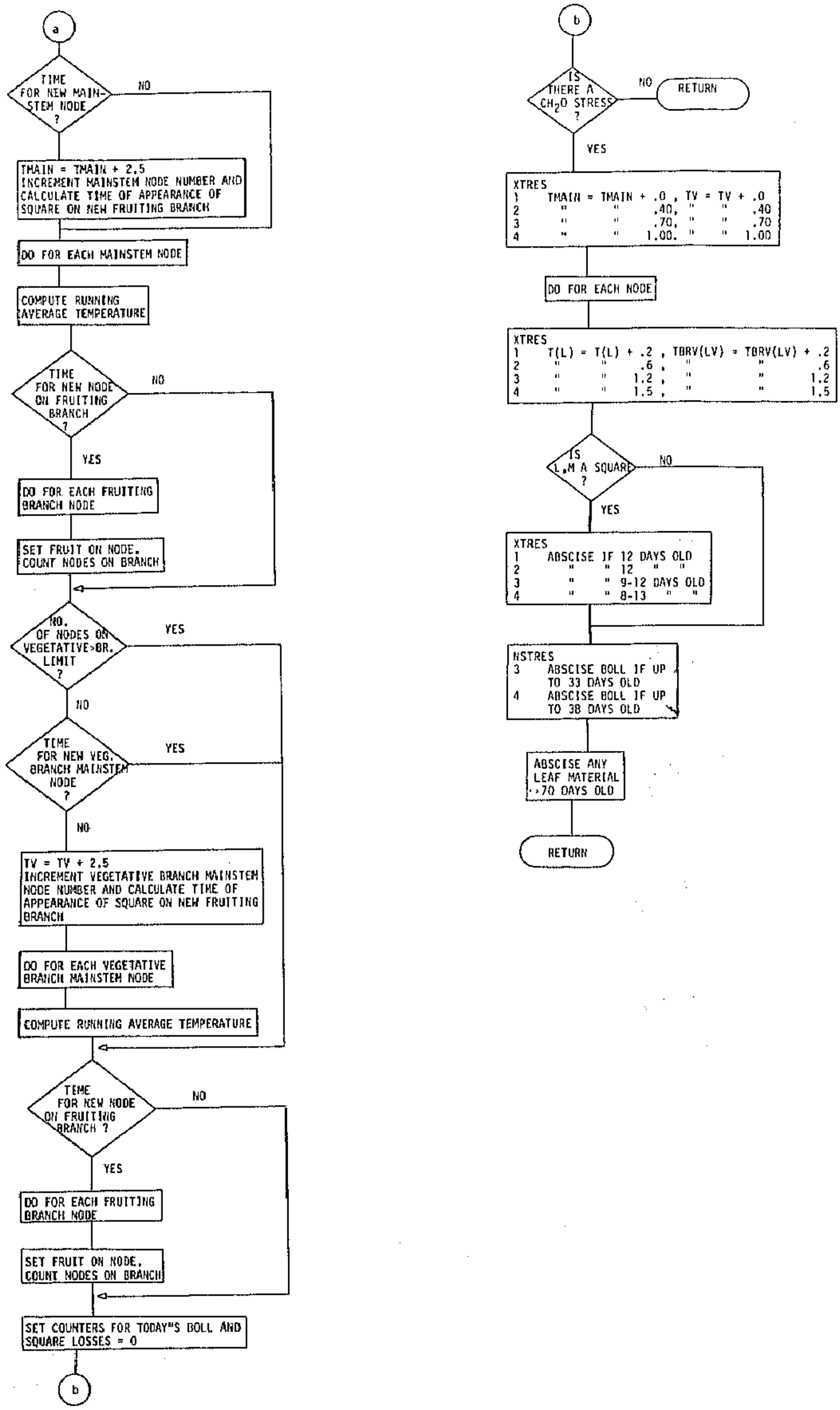
WHEN THE PLANT DEMAND EXCEEDS WHAT CAN BE TAKEN UP DAILY, A NITROGEN STRESS (NSTRES) IS DETERMINED FROM THE SEVERITY OF THE SHORTAGE. IF MORE NITROGEN IS TAKEN UP THAN CAN BE USED, THEN THIS EXCESS NITROGEN IS STORED IN LEAVES, STEMS, AND ROOTS AND THE RESERVE NITROGEN THAT THE PLANT CAN DRAW ON FOR GROWTH IS CALCULATED AS A FUNCTION OF TOTAL STEM, ROOT AND LEAF WEIGHT. THUS WHEN THE PLANT IS IN A SHORTAGE SITUATION IN WHICH THE DEMAND IS MORE THAN SUPPLY OF NITROGEN THAT CAN BE TAKEN UP FROM THE SOIL POOL OF NITROGEN BY THE ROOT SYSTEM, THE PLANT CAN DRAW ON THE RESERVE NITROGEN POOL WHICH CONSISTS OF NITROGEN STORED IN ROOTS, STEMS, AND LEAVES. THUS A COMPLETE NITROGEN BALANCE IS PERFORMED BY THIS SUBROUTINE.

SUBROUTINE PLTMAP



THIS PROGRAM INITIATES SQUARES, MAINSTEM NODES, FRUITING BRANCH INTERNODES, AND A SINGLE VEGETATIVE BRANCH. BOLINC IS COMPUTED BASED ON TODAYS BOLL GROWTH DIVIDED BY THE POTENTIAL GROWTH. CARBOHYDRATE STRESS IS THEN COMPUTED FROM BOLINC. PINHEAD SQUARES ARE ABSCISED IF SOLAR RADIATION IS GREATER THAN 700 WATTS/M^2. DELAYS IN FORMING NEW MAINSTEM NODES AND FRUITING BRANCH INTERNODES ARE GENERATED IF THERE IS A CARBOHYDRATE STRESS. SQUARES OF AN AGE CENTERED AT 12 DAYS ARE ABSCISED IN RESPONSE TO CARBOHYDRATE STRESS ALSO.




a
TIME FOR NEW MAIN-STEM NODE ?
NO
TMAIN = TMAIN + 2.5
INCREMENT MAINSTEM NODE NUMBER AND CALCULATE TIME OF APPEARANCE OF SQUARE ON NEW FRUITING BRANCH
DO FOR EACH MAINSTEM NODE
COMPUTE RUNNING AVERAGE TEMPERATURE
TIME FOR NEW NODE ON FRUITING BRANCH ?
NO
YES
DO FOR EACH FRUITING BRANCH NODE
SET FRUIT ON NODE. COUNT NODES ON BRANCH
NO. OF NODES ON VEGETATIVE>BR. LIMIT ?
YES
NO
TIME FOR NEW VEG. BRANCH MAINSTEM NODE ?
YES
NO
TV = TV + 2.5
INCREMENT VEGETATIVE BRANCH MAINSTEM NODE NUMBER AND CALCULATE TIME OF APPEARANCE OF SQUARE ON NEW FRUITING BRANCH
DO FOR EACH VEGETATIVE BRANCH MAINSTEM NODE
COMPUTE RUNNING AVERAGE TEMPERATURE
TIME FOR NEW NODE ON FRUITING BRANCH ?
NO
YES
DO FOR EACH FRUITING BRANCH NODE
SET FRUIT ON NODE. COUNT NODES ON BRANCH
SET COUNTERS FOR TODAY"S BOLL AND SQUARE LOSSES = 0
b
b
IS THERE A CH2O STRESS ?
NO
RETURN
YES
XTRES
1 TMAIN = TMAIN + .0 , TV = TV + .0
2 " " .40, " " .40
3 " " .70, " " .70
4 " " 1.00, " " 1.00
DO FOR EACH NODE
XTRES
1 T(L) = T(L) + .2 , TBRV(LV) = TBRV(LV) + .2
2 " " .6 , " " .6
3 " " 1.2 , " " 1.2
4 " " 1.5 , " " 1.5
IS L,M A SQUARE ?
NO
YES
XTRES
1 ABSCISE IF 12 DAYS OLD
2 " " 12 " "
3 " " 9-12 DAYS OLD
4 " " 8-13 " "
NSTRES
3 ABSCISE BOLL IF UP TO 33 DAYS OLD
4 ABSCISE BOLL IF UP TO 38 DAYS OLD
ABSCISE ANY LEAF MATERIAL >70 DAYS OLD
RETURN

DEFINITION OF TERMS

Main Program

ADD — Factor used to adjust LAI for different plant populations.
AGE — Counter for real time.
ALAIFC — Leaf area ratio (leaf area/leaf weight).
ATL(3) — Not used.
BALECT — Bales per acre.
BALEFC — Used in determining flowering rate based on plant population.
BLOOM — Number of fruit lost due to bloom sticking.
BOLINC(J) — Percentage of total boll demand, dry weight, added each day. J is time from emergence.
BOLLST — Number of bolls lost on a given day due to carbohydrate shortage.
BOLRES — Boll respiration.
CLIMAT(J,I) — Same as KLYMAT, but used to store weather data that is used in growing season. Julian day changed to day from emergence.
CLIMXX — Variable used to reorder weather data based on days from emergence rather than Julian day.
COSLAT — COS(LATUDE).
COTXX — Weight of mature bolls.
CO2 — Carbon dioxide fertilization trigger. Read in with weather data.
DAY — Physiological time. Real variable.
DAYFAC — Factor used in calculating length of daytime physiological time.
DECL (365) — Variable used for calculating daily declination values.
DECLIN(365) — Table of declinations read in.
DIFSUM — Not used.
DMACRE — Number of square decimeters in 1 acre.
EFF — Factor for adjusting photosynthetic efficiency of plant.
ESUBT(I) — Evapotranspiration of plant ESUBT. (I) has five values.
EVAPFC — Maximum transpiration considering pan evaporation.
FAGE(L,M) — Fruitage matrix for main plant.
FAGV(LV,MV) — Age of fruit in days from initiation at proper LV, MV location, vegetation branch.
FLOWER — Used in determining flowering rate based on plant population.
FR(L,M) — Fruiting matrix for main plant.
FRV(LV,MV) — Fruiting matrix where fruit code is stored. LV is vegetative branch main-stem node number. MV is fruiting branch off of vegetative branch node number. FRV(LV, MV) : 1 is square, 2 is green boll, 3 is mature boll, 4 is abscised fruit site, 5 is square designated to abscise, and 6 is boll designated to abscise.
GRCOTX — Weight of green bolls.
GSUBR — Vegetative respiration.
HISTD — Factor used in controlling boll setting.
H2OCAP — Water capacity of soil in inches per one-tenth of rooting depth.
H2OREM — Water remaining in soil.
H2OREX — Water remaining in soil.
H2ORUN — Calculated runoff of rainfall.
I — Physiological time. Integer variable.
IOLD — Variable used in determining whether or not a new physiological day has occurred.
ISTSQR — Trigger for subroutine PLTMAP. Time is physiological time to first square.
JB — Number used to select how often plant will be printed out. Used when LAST equals zero.
JJ — Time from emergence.
JJK — Trigger used in selecting output format of the program. First day to be listed.
JNEXT — Trigger for output in answering question from computer terminal "Do you want plant printed out on day JJ?" Answer "Zero" for "Yes;" "1" for 'No."
JPLDAY — Day of emergence.
JSEASN — SEASON+2 Trigger to end simulation.
KCARDS — Number of days of weather to be read into KLYMAT by the computer.
KLYMAT(J,I) — Environmental input to program. J is maximum number of days, equal to 300. I refers to different environmental variables. 1 is solar radiation in langleys per day. 2 is maximum daily temperature in degrees Fahrenheit. 3 is minimum daily temperature in degrees Fahrenheit. 4 is rainfall in inches per day. 5 is pan evaporation in inches per day. 6 is Julian day number. 7 is a CO_2 trigger.
LAI — Leaf-area index (DM^2/DM^2).
LAST — Trigger used in modifying matrices for simulating insect damage of plant. Zero means no changes. 1 means changes in matrix.
LATUDE — Latitude of crop being simulated.
LEAFW — Previous day's leaf weight. Used in calculating senescence.
LEFRNU — Exponent used to adjust growth rate of leaves. Equal to 1.
LEFSTF — Percentage of leaf weight that can be used to store excess carbohydrate.
LEFWT — Active tissue weight of leaves. Range 0 through 70 days.
LOSTD — Standard controlling boll setting.

MATURE — SEASON + 1 Trigger to end simulation.

MINFAC — Constant used in calculating the declination. Equal to 0.0002909.

MINUTS — Variable used in calculating the declination.

NBRV — Number of nodes on longest fruiting branch of vegetative branch.

NEWDAY — Trigger used in telling when a new physiological day has occurred. 1 is new. Zero is same.

NGREEN — Not used.

NOBR1 — Number nodes on longest fruiting branch of main stem.

NONOD — Nth node of main stem.

NSUM — Total fruiting sites.

NSUMMB — Total number of mature bolls.

NSUMBO — Total number of green bolls.

NSUMNO — Number of main-stem nodes.

NSUMSQ — Total number of squares.

NUMBER — Number of fruit to be removed (changed) on main stem.

NUMBV — Number of fruit to be removed (changed) on vegetative branch.

NUMGRN — Number of green bolls.

NUMOPN — Number of open bolls.

NVEG — Nth node of vegetative branch main stem.

NYTTYM — Factor used in finding average night temperature from minimum daily temperature.

NYTFAC — Physiological time of night. Based on temperature.

PAVAIL — Available photosynthate for growth.

PBOLL(J) — Boll; weight increments. J is days from flower where flower is day 1.

PCOT(J,I) — Daily weight increment of plant parts. J is day from emergence. I classifies plant part. 1 is roots, 3 is stems, 5 is leaves, and 7 is flowers. 2, 4, 6, 8, and 9 are not used.

PLANT — Total plant weight.

PLANTW — Total plant weight less any mature boll weight.

PLTDAY — Day of emergence.

POLYNA — Polination factor. Zero is conditions favorable for polination. 1 is conditions unfavorable for polination.

POPFAC — DMACRE/POPPLT.

POPPLT — Number of plants per acre.

PQBOLX — Growth requirement of bolls on daily basis.

PREQ — Photosynthate required for 1 day's growth.

PRES — Permanent reserve of photosynthate.

PRESX — Permanent reserve of photosynthate.

PRT(L,M) PRI(L,M) — Matrices used in printing alphanumeric representation of main plant.

PRTV(LV,MV) PRIV(LV,MV) — Matrices used in listing alphanumeric representation of vegetative branch. X is square, * is green boll, # is mature boll, O is abscised fruit site or main-stem node, I is fruiting branch internode, and = is main-stem internode.

RADFAC — Radian factor used to convert degrees to radians.

RESADD — Fraction of stalk storage available per day.

RESUFC — Maximum stalk reserves as fractions of stalk weight.

RFALL — Daily rainfall.

ROOTWT — Active tissue weight of roots. Active range, O through 24 days.

ROWSP — Row spacing in centimeters.

RSUBO — Maintenance respiration as fraction of plant weight.

RTS — Root weight.

RTSRUT — Exponent used to adjust root growth.

SEASON — Length of season from day of emergence in days.

SINLAT — SIN(LATUDE).

SOILW(I) — I is 10 layers of soil. Each layer is one-tenth of rooting depth. SOILW (I) is water content of the Ith layer.

SQLOST — Number of squares lost on a given day due to carbohydrate shortage.

STMRUT — Exponent used to adjust stem growth.

STMWT — Active tissue weight of stems. Active range, 0 through 24 days.

STRLMT — Stress that stops leaf growth.

SUMLEF — Leaf weight.

SUMRTS — Root weight.

SUMSTM — Stem weight.

TIME — Real time increment.

TOPRES — Maximum leaf reserve storage of photosynthate as fraction of leaf weight.

TRES — Temporary reserve of excess photosynthate.

TRNSLF — Factor to limit translocation from leaves during day.

TTL(I) — Title; for example, "Mississippi Weather for 1961."

WTBOLL(L,M) — Total individual boll weights. L is main-stem node number. M is fruiting branch node number. The first node of a fruiting branch is on the main stem.

WTBOLV (LV,MV) — Individual boll weights on vegetative branch.

XSTRES — Carbohydrate stress. 0 through 4 integer values.

XSTRESS(7,5) — Table of values assigning a numerical value to the stress resulting from the combination of soil water content and evaporative demand as measured by pan evaporation.

Any other variables not defined above are concerned with printout of the program.

Subroutine SUNTYM

COSDCL — COS(DCLVAL).

DAYLNG — Length of daylight in hours.

DCLVAL — Declination for day JDAY.

JDAY — Julian day.

SINDCL	SIN(DCLVAL).
SUNRIZ	Time from solar noon to sunrise.

Subroutine WATERZ

EXIT	Trigger indicating that H2OEXC is less than zero.
H2ODEF	Soil water deficiency.
H2OEXC	Excess soil water after deficit has been taken care of.
K	Number of layers of soil WRT rooting depth.
KMOIST	Variable used to calculate second subscript of XSTRES(EVAP, NSW).
NSW	Subscript of array XSTRESS (EVAP,NSW).
PANVAP	Pan evaporation in inches per day.
WATER	Rainfall (irrigation).

Subroutine PHZDAZ

DAYT	Daytime physiological time based on temperature and length of day.
DAYTYM	Fractional physiological time of day.
MAXMIN	Difference between maximum daily temperature and minimum daily temperature.
NYTT	Nighttime physiological time based on temperature and length of night.
NYTTYM	Fractional physiological time of night.
TAVG	Average 24-hour temperature.

Subroutine PNET

BMAIN	Photosynthate required to maintain present plant material.
LYTCPT	Fraction of incident solar radiation intercepted as function of LAI.
LYTRES	Light respiration.
PN	Net photosynthate.
PPLANT	Photosynthate produced per plant.
PSTAND	Photosynthate produced by stand of plants as function of WATTSM.
PTS	Photosynthate after light respiration and maintenance have been subtracted.
PTSRED	Photosynthate reduction factor.
RSUBL	Coefficient for light respiration.
WATTSM	Solar radiation in watts per square meter.

Subroutine QPREQZ

F	Not used.
LEFADD	Factor used to adjust LAI for crops with different populations.
NAGE	Age of fruit from initiation of square.
PQBOLD	Boll photosynthate requirement for full growth during day.
PQBOLN	Boll photosynthate requirement for full growth during night.
PQBOLX	Total boll requirement for 24 hours.
PQLEFD	Photosynthate required for full leaf growth during day.
PQLEFN	Photosynthate required for full leaf growth during night.
PQRESN	Requirement for rebuilding depleted reserves.
PQRTSD	Photosynthate required for full root growth during day.
PQRTSN	Photosynthate required for full root growth during night.
PQSTMD	Photosynthate required for full stem growth during day.
PQSTMN	Photosynthate required for full stem growth during night.
QLEF	Not used. Equal to QUAN.
QRTS	Not used. Equal to QUAN.
QSTM	Not used. Equal to QUAN.
QUAN	Constant to obtain proper proportioning of photosynthate.

Subroutine PQDAYZ

F	Ratio of available photosynthate to that required.
ROTW	Variable used to calculate root senescence.
STMW	Variable used to calculate stem senescence.
TRESXX	Maximum photosynthate that can be translocated during day.

Subroutine PQNYTZ

ABC	Variable used to see if boll setting requirements are met.
PREQZ	Photosynthate required for growth if roots are not grown.
STQN	Same as PREQZ.
TSLIMT	Maximum photosynthate that can be stored in leaves.

Subroutine NITR

AD	Actual root volume depth.
AL	Actual root volume length.
APPL	Sidedressing.
AW	Actual root volume width.
BCON	Burr concentration of nitrogen by weight.
BOLI	Nitrogen requirement for today's boll growth.
BURMIN	Maximum nitrogen requirement for today's burr growth.
BURR	Maximum burr usage capacity for nitrogen.
BURRI	Nitrogen requirement for today's burr growth.
CD	Depth of maximum root volume per plant.
CL	Length of maximum root volume per plant.
COTTON	Total mature and green cotton weight.
CW	Width of maximum root volume per plant.
DEFCIT	Difference between boll growth requirement for nitrogen and nitrogen taken up from soil.

DREQN — Maximum capacity of plant for storage of nitrogen.
EFN — Efficiency of application of preemergence application and sidedressing (if any).
EXC — Amount of nitrogen taken up above needs of plant for growth.
GRGR — Amount of fruit growth on plant.
LCONC — Leaf concentration of nitrogen by weight.
LEFR — Maximum carbohydrate storage capacity of leaves.
LEFRI — Nitrogen requirement for today's leaf growth.
LEFRS — Reserve nitrogen stored in leaves.
NMAX(I) — Maximum nitrogen concentration possible in plant parts. I is used as follows: 1, seed; 3, burrs; 4, stems; 5, roots.
NMIN(I) — Minimum nitrogen concentrations possible in plant parts as defined for NMAX(I).
NPART — Actual nitrogen in plant parts. I is defined as NMAX(I).
NSTRES — Nitrogen stress factor for reduction of growth and abscission of fruit.
PERN — Organic nitrogen pool in soil.
POM — Percentage of organic matter.
R — Rainfall in inches.
RCON — Nitrogen concentration in roots by weight.
REQ1 — Nitrogen requirement for today's plant growth.
RESN — Reserve nitrogen available in plants for growth of fruit.
ROTR — Maximum capacity of roots for nitrogen.
ROTR1 — Nitrogen requirement for today's root growth.
ROTRS — Reserve nitrogen in roots available for fruit growth.
RTOT — Cumulative sum of nitrogen demanded by the plant.
SCON — Seed concentration of nitrogen by weight.
SEEDR — Maximum seed usage capacity for nitrogen.
SEEDR1 — Nitrogen requirement for today's fruit growth.
STCON — Nitrogen concentration in stems by weight.
STMR — Maximum capacity of stems for nitrogen.
STMR1 — Nitrogen requirement for today's stem growth.
STMRS — Reserve nitrogen in stems available for fruit growth.
SUPR — Factor used for partitioning nitrogen among plant parts.
SUPR1 — Factor used in partitioning nitrogen among plant parts.
TEMN — Soil pool of available nitrogen.
TOTAL — Plant requirement for growth plus excess nitrogen (if any) taken up.
USE — Parameter indicating rate of depletion of reserves.
VPLT — Actual root volume.
VTOT — Maximum root volume per plant.
WCOTX — Yesterday's mature cotton weight.
WGRCOT — Yesterday's green cotton weight.
WLEF — Yesterday's leaf weight.
WROT — Yesterday's root weight.
WSTM — Yesterday's stem weight.
XN — Maximum amount of nitrogen plant can take up per day.
XNUP — Nitrogen uptake of plant.
XNUP1 — Amount of nitrogen taken up by plant.

Subroutine PLTMAP

AVTEMP — Accumulated average temperature for first 31 physiological days.
DSQ — Day of squaring on main stem.
DSV — Day of squaring on vegetative branch.
ICNOD — Trigger for adding new node to main-stem fruiting branch.
INOD — Main-stem node on plant at which the first square will appear.
ISQ — Trigger for telling when first square is on plant.
IVNOD — Trigger for adding new node to vegetative fruiting branch.
JK
JKV — Matrices for determining when fruit will be abscised after triggering the abscission process.
LEAFWT(JJ) — Variable used to senesce leaf material.
NOBR — Maximum number of nodes on a main-stem fruiting branch.
NTL — Trigger for adding squares to a fruiting branch. from the main stem.
NTLV — Trigger for adding squares to a fruiting branch for a vegetative branch.
NV — Number of nodes on vegetative main stem.
PQBOLD — Photosynthate available for today's boll growth.
PQBOLN — Photosynthate available for tonight's boll growth.
PQBOLX — Total required photosynthate for maximum boll growth for 24 hours.
ROOTW(JJ) — Variable used to senesce root material.
STEM(JJ) — Variable used to senesce stem material.
TAVL — Running average temperature of nodes on main stem.
TBRV — Time till next node on vegetative fruiting branch.
T(L) — Time till next node on main-stem fruiting branch.
TMAIN — Time till next node on main stem.
TMPV — Running average temperature of nodes on vegetative branch.

TV	Time till next node on vegetative main stem.
WLOST	Total root and stem material senesced on this day.
XM	Variable used in calculating maximum number of nodes on a mainstem fruiting branch, based on plant population.

PROGRAM SETUP AND EXECUTION

SIMCOT II is written in FORTRAN IV level G and has been run on the IBM 370-155 system at Clemson University and on the UNIVAC 1106 at Mississippi State University. The IBM 370-155 uses 91 K bytes of storage, and run time with a typical 10-day mapping output is 55 seconds. Comparable figures for the Univac 1106 are 23 K words and 34 seconds. We normally employ disk files for program and data sets, and we usually operate from terminal. In converting to Univac or IBM equipment the arc cosine term in SUNTYM must be used appropriately.

SIMCOT II can be used for plant population studies with up to 80,000 plants per acre. An appropriate "LEFADD" factor from table 4–1 and the per-acre plant population must be supplied as indicated on line 288 of the sample data.

Carbon dioxide fertilization experiments can be made by inserting a 1 in the appropriate column of the climate data. This provides 500 p/m CO_2 in the upper part of the plant canopy during 6 midday hours (roughly equivalent to 200 lb CO_2/acre/hour).

Photosynthetic efficiency can be varied by appropriate change in PNEFF in line 288 of sample data.

Nitrogen fertility studies can be made with different planting applications (INITIALN= pounds N per acre on line 290 of the sample data set) or by sidedressing with appropriate levels of APPL in pounds N per acre on line 36 of NITR.

Row-spacing studies can be made by changing ROWSP on line 288 of the sample data.

Soil-moisture studies require appropriate values for inches of water holding capacity in the top 12 inches (SOIL CAP on line 288 of the sample data) and may require changes in lines 18–24 of WATERZ on lines 281 to 283 of the sample data to reflect the effect of various climates on plant water status. We have not yet attempted to validate over a range of moisture stress conditions for different soils.

Emergence date studies can be done by changing EMERGE on line 288 of the sample data.

PROGRAM LISTING

MCKIN*TF.K

```
      BLOCK DATA
      COMMON /COM/FR, DAY, I, JJ, PCOT, ISTSQR
      INTEGER FR(45, 8 )
      DATA FR/360*0/
      REAL PCOT(200, 9)
      DATA DAY/0./, ISTSQR/0/
      END
```

MCKIN*TF.A

```
      DIMENSION PCOT(200, 9), PBOLL(50), KLYMAT(300, 7), XSTRES(
     &7, 5), WTBOLL(45, 8 ), CLIMAT(300, 7)
      DIMENSION SOILW(10), ESUBT(5),          WTBOLV(30, 5)
      INTEGER TTL(20)
      DIMENSION DECL(365), DECLIN(365)
      DIMENSION ATL(4)
      COMMON /COM/FR, DAY, I, JJ, PCOT, ISTSQR
      COMMON STMWT, ROOTWT
      INTEGER FR(45, 8 )
      INTEGER SQLOST, BOLLST, BLOOM, FRVL
      INTEGER CHARX/'X'/, CHARS/'*'/, CHARN/'#'/, CHARI/'I'/, CHARO/'O'/
      INTEGER FRV(30, 5)/150*0/, FAGV(30, 5)/150*0/, PRTV(30, 5)/150*' '/,
     1PRIV(30, 5)/150*' '/
      INTEGER XTRES/0/, CO2/0/
      INTEGER FAGE(45, 8 )/360*0/, POLYNA/0/
      INTEGER PRT(45, 8 )/360*' '/, PRI(45, 8 )/360*' '/
      REAL NMAX(5), NMIN(5), NPART(5)/5*0./, LCONC/0./
      REAL LEAFW
      REAL LEFWT, LO STD, LAI,                         NYTFAC,             NYTT
     1YM,        LATUDE, MINUTS, MINFAC, KLYMAT,                 LEFSTF
      REAL WLOST(3)/3*0./, AGE/0./
      DATA WTBOLL/360*0./, HISTD/.1/, LOSTD/.2/, STRLMT/.71/, TRNSLF/.2/
      DATA WTBOLV/150*0./, DAYFAC/.55/, NYTFAC/.45/, EVAPFC/.75/, RSUBO/
     1.0032/, ALAIFC/1.2/, TOPRSF/0./, RESUFC/.6/, RESADD/.8/, GSUBR/.375/,
     2LEFSTF/.3/, NMIN(1)/.02/, NMIN(2)/.04/, NMIN(3)/.006/, NMIN(4)/.009/,
     3NMAX(1)/.042/, NMAX(2)/.04/, NMAX(3)/.02/, NMAX(4)/.02/
      DATA ATL/'DAY', ' VS', ' BOL', ' INC'/
      DATA SUMLEF/0./, SUMSTM/0./, SUMRTS/0./, GRCOTX/0./, NUMGPN/0/, NUMOPN/
     10/, DIFSUM/0./, DMACRE/404700./, COTXX/0./, TOPRES/0./, PAVAIL/0./, TRES
     2/0./,          POLYNA/0/, SQLOST/0/, BOLLST/0/, LAI/.01/, PLANTW/1./,
     3 PRESX/.01/, PQBOLX/1./, PRES/.01/, RTS/1./, PREQ/0./, NEWDAY/
     40/, IOLD/0/, H2ORUN/0./
      READ(5, 1000)((PCOT(K, J), J=1, 9), K=1, 41)
 1000 FORMAT(9F5.0)
      READ(5, 1005)(PBOLL(J), J=1, 60)
 1005 FORMAT(16F5.0)
      READ(5, 1003)TTL
 1003 FORMAT(20A4)
      READ(5, 1001)KCARDS
 1001 FORMAT(I10)
      READ(5, 1010)((KLYMAT(K, J), J=1, 7), K=1, KCARDS)
 1010 FORMAT(7F10.0)
      READ(5, 1025)(DECLIN(J), J=1, 365)
 1025 FORMAT(16F5.2)
      DO 2222 J=2, 365
 2222 IF(ABS(DECLIN(J)).LT.0.5)DECLIN(J)=DECLIN(J-1)
      READ(5, 1015)((XSTRES(J, K), K=1, 5), J=1, 7)
 1015 FORMAT(15F5.0)
      DO 786 J=42, 200
      PCOT(J, 1)=.08
      PCOT(J, 2)=.0
      PCOT(J, 3)=.80
      PCOT(J, 4)=0.
      PCOT(J, 5)=.60
      PCOT(J, 6)=.0
      PCOT(J, 7)=PCOT(41, 7)
      PCOT(J, 8)=0.
  786 PCOT(J, 9)=15.00
```

PROGRAM LISTING—Continued

```
C DESCRIPTIONS OF THE ENVIRONMENT: LATITUDE, LENGTH OF SEASON,WATER
C CAPACITY OF THE SOIL IN INCHES PER TENTH OF THE ROOTING DEPTH
6       READ(5,1020)LATUDE,SEASON,H2OCAP,EMERGE,ROWSP,ADD,EFF,POPPLT
C MANAGEMENT O& THE CR-P: PLANTING DAY -& THE YEAR, PLANTS PER ACRE
C       ROW SPACING, CENTIMETERS
2       READ(5,1020)POM,EFN,TEMN,RESIDN
 1020 FORMAT(8F10.0)
        TEMN=(TEMN*EFN/POPPLT)*453.6+RESIDN*453.6/POPPLT
        READ(5,7055)JJK,LAST,JB
7055   FORMAT(3I5)
        FLOWER=30000/POPPLT
        BALEFC=.0000014*POPPLT
        WS=0
        WR=0
        WL=0
        MINFAC=.0002909
        JSEASN=SEASON+2.
        MATURE=SEASON+1.
        NGREEN=SEASON-2.
        RADFAC=.0174533
        LATUDE=LATUDE*RADFAC
        JPLDAY=EMERGE
        SINLAT=SIN(LATUDE)
        COSLAT=COS(LATUDE)
        DO 8 J=1,365
        K=DECLIN(J)
        DEGRES=K
        MINUTS=DECLIN(J)-DEGRES
      8 DECL(J)=DEGRES*RADFAC+MINUTS*MINFAC*100.
        K=1
        DO 21 J=1,KCARDS
        CLIMXX=KLYMAT(J,6)-EMERGE
        IF(CLIMXX.LE.0.)GO TO 21
        CLIMAT(K,7)=KLYMAT(J,7)
        CLIMAT(K,6)=KLYMAT(J,6)
        CLIMAT(K,5)=KLYMAT(J,5)
        CLIMAT(K,4)=KLYMAT(J,4)
        CLIMAT(K,3)=(KLYMAT(J,3)-32.)*5./9.
        CLIMAT(K,2)=(KLYMAT(J,2)-32.)*5./9.
        CLIMAT(K,1)=KLYMAT(J,1)
        K=K+1
     21 CONTINUE
        ESUBT(1)=EVAPFC*.5
        ESUBT(2)=EVAPFC*.7
        ESUBT(3)=EVAPFC*.8
        ESUBT(4)=EVAPFC*.9
        ESUBT(5)=EVAPFC
        POPFAC=DMACRE/POPPLT
        ROOTWT=PCOT(1,1)
        STMWT =PCOT(1,3)
        LEFWT=PCOT(1,5)
        I=1
        WRITE(6,1004)TTL
1004   FORMAT(' ',20A4)
        DO 145 J=1,10
    145 SOILW(J)=H2OCAP
        TIME=1.
        DO 998 JJ=1,JSEASN
        JNEXT=0
        AGE=AGE+TIME
        IF(AGE.GT.SEASON)GO TO 998
        H2OREM=0.
        RFALL=CLIMAT(JJ,4)
        CALL SUNTYM(JPLDAY,DECL,DAYLNG,SINLAT,COSLAT)
        CALL WATERZ(CLIMAT,H2OCAP,H2ORUN,STRESS,XSTRES,SOILW,ESUBT,H2ODEF)
        CALL PHZWAZ(CLIMAT,DAYFAC,NYTFAC,DAYLNG,IOLD,TDAY,TNYT,DAYTYM,
       1NYTTYM,TFACD,TFACN,NEWDAY,TAVG)
        CALL PNET(LAI,CLIMAT,POPFAC,PLANTW,DAYTYM,NYTTYM,RSUBO,PN,STRESS,
       1TDAY,LYTRES,GSUBR,CO2,EFF,ROWSP,NMIN,LCONC)
        CALL QPREQZ(PQLEFD,PQLEFN,PQSTMD,PQSTMN,PQRTSD,PQRTSN,PQBOLD,PQBOL
       1N,PQRESN,PQFLR,PBOLL,NYTTYM,DAYTYM,PQBOLX,TFACD,TFACN,TOPRES,PRES,
       2RESADD,NEWDAY,LEFWT,SUMLEF,SUMSTM,SUMRTS,
       3INOD,NONOD,NOBR,FAGE,NVEG,NBRV,FRV,FAGV,NFL,ADD,NSTRES)
        CALL PQDAYZ(STRESS,STRLMT,PQLEFD,PQSTMD,PQRTSD,PQBOLD,TRES,PRES,
       1PN,RESUFC,LEFWT,XTRES,TRNSLF,LEAFW,STMW,ROTW)
        CALL PQNYTZ(PQLEFN,PQSTMN,PQRTSN,PQBOLN,PQRESN,PQFLR,TRES,
```

PROGRAM LISTING—Continued

```
     1LEFWT,PRES,TOPRES,HISTD,LOSTD,XTRES,LEFSTF,POLYNA,RESUFC,
     2PN,TOPRSF,STRESS,RFALL)
      CALL PLTMAP(PBOLL,WTBOLL,TAVG,NEWDAY,PQBOLN,PQBOLD,PQBOLX,XTRES,
     1NOBR1,NONOD,BOLLST,SQLOST,COTXX,GRCOTX,ROWSP,PQFLR,POLYNA,FAGE,
     2INOD,NOBR,POPPLT,NUMGRN,NUMOPN,NVEG,NBRV,FRV,FAGV,WTBOLV,NV,BLOOM,
     3LEAFW,LEFWT,NFL,CLIMAT,STMW,ROTW,GBLOS,WLOST,NSTRES)
      CALL NITR(RDEP,POM,EFN,TEMN,NMAX,NMIN,     ROWSP,PERN,POPPLT,
     1NPART,NSTRES,RESN,DREQN,DEFCIT,USE,LCONC,H2ODEF,H2OCAP,GBLOS,
     2LEFWT,COTXX,GRCOTX,RFALL,JJK,FRVL,WS,WR)
      WS=WS+WLOST(1)
      WR=WR+WLOST(2)
      PLANT=LEFWT+STMWT+ROOTWT+GRCOTX+COTXX+PRES+WLOST(1)+WLOST(2)+WLOS
     *T(3)
      PLANTW=PLANT-COTXX
      DO 180 J=1,10
  180 H2OREM=H2OREM+SOILW(J)
      H2OREX=H2OREM
      BALECT=COTXX*BALEFC
      LAI=LEFWT*ALAIFC/POPFAC
      IF(I.LT.ISTSQR+1)GO TO 750
      NSUM=0
      NSUMMB=0
      NSUMNO=0
      NCOUNT=0
      NSUMSQ=0
      NSUMBO=0
      DO 728 L=1,NONOD
      DO 728 M=1,NOBR1
      IF(FR(L,M).EQ.0)GO TO 728
      IF(FR(L,M).EQ.1)PRT(L,M)=CHARX
      IF(FR(L,M).EQ.2)PRT(L,M)=CHARS
      IF(FR(L,M).EQ.3)PRT(L,M)=CHARN
      IF(FR(L,M).EQ.4)PRT(L,M)=CHARO
      IF(FR(L,M).EQ.5)PRT(L,M)=CHARX
      IF(FR(L,M).EQ.6)PRT(L,M)=CHARS
      IF(FR(L,M).EQ.1.OR.FR(L,M).EQ.5)NSUMSQ=NSUMSQ+1
      IF(FR(L,M).EQ.1.AND.FAGE(L,M).GE.12)NCOUNT=NCOUNT+1
      IF(FR(L,M).EQ.5.AND.FAGE(L,M).GE.12)NCOUNT=NCOUNT+1
      IF(FR(L,M).EQ.2.OR.FR(L,M).EQ.6)NSUMBO=NSUMBO+1
      IF(FR(L,M).EQ.3)NSUMMB=NSUMMB+1
      IF(FR(L,M).EQ.4)NSUMNO=NSUMNO+1
      PRI(L,M)=CHARI
  728 CONTINUE
      DO 828 LV=1,NVEG
      DO 828 MV=1,NBRV
      IF(FRV(LV,MV).EQ.0) GO TO 828
      IF(FRV(LV,MV).EQ.1)PRTV(LV,MV)=CHARX
      IF(FRV(LV,MV).EQ.2)PRTV(LV,MV)=CHARS
      IF(FRV(LV,MV).EQ.3)PRTV(LV,MV)=CHARN
      IF(FRV(LV,MV).EQ.4)PRTV(LV,MV)=CHARO
      IF(FRV(LV,MV).EQ.5)PRTV(LV,MV)=CHARX
      IF(FRV(LV,MV).EQ.6)PRTV(LV,MV)=CHARS
      IF(FRV(LV,MV).EQ.1.OR.FRV(LV,MV).EQ.5)NSUMSQ=NSUMSQ+1
      IF(FRV(LV,MV).EQ.1.AND.FAGV(LV,MV).GE.12)NCOUNT=NCOUNT+1
      IF(FRV(LV,MV).EQ.5.AND.FAGV(LV,MV).GE.12)NCOUNT=NCOUNT+1
      IF(FRV(LV,MV).EQ.2.OR.FRV(LV,MV).EQ.6)NSUMBO=NSUMBO+1
      IF(FRV(LV,MV).EQ.3)NSUMMB=NSUMMB+1
      IF(FRV(LV,MV).EQ.4)NSUMNO=NSUMNO+1
      PRIV(LV,MV)=CHARI
  828 CONTINUE
      IF(LAST.EQ.0)GO TO 5005
      IF(JJ.NE.JJK)GOTO 7000
      WRITE(6,211)JJ
211   FORMAT(' ','HOW MANY FRUIT ON MAIN BRANCH WILL BE ABSCISED ON DAY
     1',I4,'?')
      READ(5,3065) NUMBER
      WRITE(6,3065)NUMBER
 3065 FORMAT(I5)
      IF(NUMBER.LE.0)GO TO 30
      DO 31 I=1,NUMBER
      WRITE(6,212)JJ
212   FORMAT(' ','WHICH FRUIT ON MAIN  BRANCH WILL BE ABSCISED ON DAY ',
     1I4,'?')
      READ(5,1)L,M,FR(L,M)
      WRITE(6,1)L,M,FR(L,M)
31    CONTINUE
```

PROGRAM LISTING—Continued

```
   30    CONTINUE
         WRITE(6,214)JJ
  214    FORMAT(' ','HOW MANY FRUIT ON VEG. BRANCH WILL BE ABSCISED ON DAY
        1',I4,' ?')
         READ(5,3065) NUMBV
         WRITE(6,3065)NUMBV
         IF(NUMBV.LE.0)GO TO 33
         DO 32 I=1,NUMBV
         WRITE(6,215)JJ
  215    FORMAT(' ','WHICH FRUIT ON VEG. BRANCH WILL BE ABSCISED ON DAY
        1I4,'?')
         READ(5,1)LV,MV,FRV(LV,MV)
         WRITE(6,1)LV,MV,FRV(LV,MV)
    1    FORMAT(5I5)
   32    CONTINUE
   33    CONTINUE
         WRITE(6,216)JJ
  216    FORMAT(' ','DO YOU WANT PLANT  PRINTED OUT ON DAY ',I4,'?')
         READ(5,1)JNEXT
         WRITE(6,1)JNEXT
         JJK=JJK+JNEXT
         WRITE(6,213)JJ
  213    FORMAT(' ','IS THERE ANY MORE DATA AFTER DAY ',I4,'?')
         READ(5,3070)LAST
         WRITE(6,3070)LAST
 3070    FORMAT(I5)
 7000    CONTINUE
 5005    CONTINUE
         NSUM=NSUMSQ+NSUMBO+NSUMNO+NSUMMB-NONOD-NV
 8010    CONTINUE
         IF(NOBR1.LT.2)GO TO 746
         NOBR2=NOBR1-1
         DO 738 M=1,NOBR2
         M1=NOBR1-M+1
         IF(JJ.NE.JJK)GO TO 8001
         WRITE(6,739)(PRT(L,M1),L=1,NONOD,2)
     739 FORMAT(' ',2X,32(A1,3X))
 8001    CONTINUE
         IF(JJ.NE.JJK)GO TO 8007
         WRITE(6,739)(PRI(L,M1),L=1,NONOD,2)
 8007    CONTINUE
  738    CONTINUE
  746    CONTINUE
         IF(JJ.NE.JJK)GO TO 8008
         WRITE(6,740)(PRT(L,1),L=1,NONOD)
     740 FORMAT(' ','==',64(A1,'='))
 8008    CONTINUE
         IF(NOBR1.LT.2)GO TO 750
         IF(JJ.NE.JJK)GO TO 8002
         DO 741 M=2,NOBR1
         WRITE(6,760)(PRI(L,M),L=2,NONOD,2)
     741 WRITE(6,760)(PRT(L,M),L=2,NONOD,2)
     760 FORMAT(' ',4X,32(A1,3X))
     750 CONTINUE
         IF(JJ.NE.JJK)GO TO 8002
         WRITE(6,751)JJ,XTRES,STRESS,CLIMAT(JJ,1),PLANT
  751    FORMAT(' ','DAY ',I3,'  CH2O STRESS ',I1,'  H2O STRESS ',F4.1,'
        1SOLAR RAD ',F5.0,'  PLANT WT ',F6.2)
         WRITE(6,752) SQLOST,BOLLST,LAI,I,BLOOM
  752    FORMAT(' ','SQUARES LOST ',I2,'  BOLLS LOST ',I2,'  LAI ',F4.2,
        1'  PHYSIOL. DAYS ',I3,'  BLOOMS LOST ',I2)
         WRITE(6,753)LEFWT,NONOD,NSUMSQ,NSUMBO,NSUM
  753    FORMAT(' ','LEAF WT ',F5.2,'  MAINSTEM NODES ',I2,' # SQUARES '
        2,I3,' # GREEN BOLLS ',I2,' # SITES ',I3,//)
   8002 CONTINUE
         IF(I.LT.ISTSQR+1) GO TO 870
         NBRV2=NBRV-1
         IF(NBRV2.LT.1) GO TO 846
         DO 838 MV=1,NBRV2
         MV1=NBRV-MV+1
         IF(JJ.NE.JJK)GO TO 8009
         WRITE(6,739) (PRTV(LV,MV1),LV=1,NVEG,2)
         WRITE(6,739) (PRIV(LV,MV1),LV=1,NVEG,2)
 8009    CONTINUE
  838    CONTINUE
  846    CONTINUE
         IF(JJ.NE.JJK)GO TO 8003
```

```
              WRITE(6,740) (PRTV(LV,1),LV=1,NV)
        8003  CONTINUE
              IF(NBRV2.LT.1) GO TO 850
              IF(JJ.NE.JJK)GO TO 8005
              DO 841 MV=2,NBRV
              WRITE(6,760) (PRIV(LV,MV),LV=2,NVEG,2)
          841 WRITE(6,760) (PRTV(LV,MV),LV=2,NVEG,2)
        8005  CONTINUE
          850 CONTINUE
              INODV=INOD-1
              IF(JJ.NE.JJK)GO TO 870
              IF(INODV.LT.0)GO TO 870
              WRITE(6,901) INODV
          901 FORMAT(' ','VEGETATIVE BRANCH GROWING FROM NODE',I3,2X,'OF THE MAI
             1N STEM',//)
        8006  CONTINUE
        870   CONTINUE
              JJK=JJK-JNEXT
              IF(JJ.NE.JJK)GO TO 8011
              IF(LAST.EQ.0)GO TO 5515
              WRITE(6,220)JJ
        220   FORMAT(' ','THIS IS DAY ',I4,5X,'WHAT IS THE NEXT OUTPUT DAY?')
              READ(5,3065)JJK
        5515  CONTINUE
              IF(LAST.EQ.1)GO TO 5505
              JJK=JJK+JB
        5505  CONTINUE
        8011  CONTINUE
          998 CONTINUE
              LATUDE=LATUDE/RADFAC
              WRITE(6,1050)BALECT,EMERGE,JSEASN,LATUDE
        1050  FORMAT(' ',' YIELD/ACRE ',F5.3,'  EMERGENCE DATE ',F4.0,'  GROWING
             1DAYS ',I3,'  LATITUDE ',F5.1)
              WRITE(6,1051)NUMGRN,NUMOPN,H2OCAP
        1051  FORMAT(' ','# GREEN BOLLS ',I2,' # OF OPEN BOLLS ',I2,'  SOIL H2O
             2 CAPACITY ',F4.2)
              WRITE(6,1052)H2ORUN,ROWSP,POPPLT
        1052  FORMAT(13H H2O RUN OFF ,F4.2,14H  ROW SPACING ,F6.1,19H  # OF PLAN
             1TS/ACRE ,F7.0)
              STOP
              END
```

```
CPRT TF.B
```

```
MCKIN*TF.B
              SUBROUTINE SUNTYM(    JPLDAY,DECL,DAYLNG,SINLAT,COSLAT)
      C       THIS SUBROUTINE COMPUTES THE LENGTH OF DAY FOR ANY DAY OF THE YEAR
      C       JPLDAY IS THE DAY OF PLANTING, DAYLNG IS THE DURATION OF SUNLIGHT
      C       IN HOURS.
      C       DECL REFERS TO A TABLE OF DECLINATIONS GIVING DECLINATIONS FOR EAC
              DIMENSION DECL(365),PCOT(200,9)
              COMMON /COM/FR,DAY,I,JJ,PCOT,ISTSQR
              INTEGER FR(45,8 )
              RADFAC=.0174533
              JDAY=JJ+JPLDAY
              DCLVAL=DECL(JDAY)
              SINDCL= SIN(DCLVAL)
              COSDCL=COS(DCLVAL)
              SUNRIZ=(-SINLAT*SINDCL)/(COSLAT*COSDCL)
              SUNRIZ= ACOS(SUNRIZ)/RADFAC
              DAYLNG=(SUNRIZ/15.)*2.
              RETURN
              END
```

```
MCKIN*TF.C
              SUBROUTINE WATERZ(    CLIMAT,H2OCAP,H2ORUN,STRESS,XSTRES,SOILW,
             1ESUBT,H2ODEF)
      C       SUBROUTINE WATERZ ADJUSTS SOIL MOISTURE FOR EVAPORATION AND
      C       RAINFALL AND EVALUATES PLANT STRESS IN TERMS OF WATER REMAINING IN
      C       THE SOIL AND THE PAN EVAPORATION FOR THE DAY - ARBITRARILY.
      C       CLIMAT IS RAINFALL AND PAN EVAPORATION FOR THE DAY INDICATED
```

PROGRAM LISTING—Continued

```
      C      H2OCAP IS THE USEFUL WATER IN INCHES PER TENTH OF THE ROOTING
      C      DEPTH
      C      H2ORUN IS THE COMPUTED RUNOFF OR SOAKTHROUGH
      C      XSTRESS REFERS TO A TABLE OF VALUES ASSIGNING A NUMERICAL VALUE TO
      C      THE STRESS RESULTING FROM THE COMBINATION OF SOIL WATER CONTENT AN
      C      EVAPORATIVE DEMAND AS MEASURED BY PAN EVAPORATION
      C      SOILW IS THE USEFUL WATER PER TENTH OF THE ROOTING DEPTH
             DIMENSION CLIMAT(300,7),XSTRES(7,5),SOILW(10),ESUBT(5),PCOT(200,9)
             INTEGER EVAP,FR(45,8 )
             COMMON /COM/FR,DAY,I,JJ,PCOT,ISTSQR
             COMMON  STMWT,ROOTWT
             IF(CLIMAT(JJ,5).LT.2.0)EVAP=7
             IF(CLIMAT(JJ,5).LT..47)EVAP=6
             IF(CLIMAT(JJ,5).LT..39)EVAP=5
             IF(CLIMAT(JJ,5).LT..31)EVAP=4
             IF(CLIMAT(JJ,5).LT..23)EVAP=3
             IF(CLIMAT(JJ,5).LT..15)EVAP=2
             IF(CLIMAT(JJ,5).LT..07)EVAP=1
             H2ODEF=0.
             IF(CLIMAT(JJ,4).LT..02)GO TO 175
             DO 153 J=1,10
         153 H2ODEF=H2ODEF+H2OCAP-SOILW(J)
             H2OEXC=CLIMAT(JJ,4)-H2ODEF
             IF(H2OEXC.GT.0.)GO TO 154
             EXIT=0.
             WATER=CLIMAT(JJ,4)
             DO 151 J=1,10
             IF(EXIT.GT.0.)GO TO 151
             XWATER=WATER
             WATER=WATER-H2OCAP+SOILW(J)
             IF(WATER.GT.0.)GO TO 152
             SOILW(J)=SOILW(J)+XWATER
             EXIT=1.
             GO TO 151
         152 SOILW(J)=H2OCAP
         151 CONTINUE
             GO TO 175
         154 H2ORUN=H2ORUN+H2OEXC
             DO 155 J=1,10
         155 SOILW(J)=H2OCAP
         175 EXIT=0.
             PANVAP=CLIMAT(JJ,5)
             K=10
             DO 178 J=1,10
             QH2O=SOILW(J)
             IF(EXIT.GT.0.)GO TO 178
             IF(SOILW(J).GT.0.)GO TO 176
             K=K-1
             IF(K.LE.0)K=1
             GO TO 178
         176 KMOIST=((K*5)+5)/10
             PANVAP=PANVAP*ESUBT(KMOIST)
             SOILW(J)=SOILW(J)-PANVAP
             IF(SOILW(J).GT.0.)GO TO 177
             PANVAP=PANVAP-QH2O
             NSW=KMOIST
             GO TO 178
         177 EXIT=1.
             NSW=KMOIST
             PANVAP=0.
         178 CONTINUE
             STRESS=XSTRES(EVAP,NSW)
             RETURN
             END
```

```
MCKIN*TF.D
             SUBROUTINE PHZDAZ(    CLIMAT,DAYFAC,NYTFAC,DAYLNG,        IOLD,
            1TDAY,TNYT,DAYTYM,NYTTYM,TFACD,TFACN,NEWDAY,TAVG)
      C      DAYFAC IS FRACTION ABOVE MINTEMP FOR DAILY TEMP. AVG.
      C      NYTFAC IS FRACTION ABOVE MINTEMP FOR NIGHT TEMP. AVG.
      C      SUBROUTINE PHZDAZ CALCULATES THE LENGTH OF THE PHYSIOLOGICAL DAY A
      C      BASED ON THE ESTIMATED AVERAGE TEMPERATURE OF EACH, DEG.CENTIGRADE
      C      IOLD=PHYSIOLOGICAL TIME,DEGREE-DAYS FROM START OF PLANT GROWTH
             DIMENSION CLIMAT(300,7),PCOT(200,9)
```

PROGRAM LISTING—Continued

```
      COMMON /COM/FR, DAY, I, JJ, PCOT, ISTSQR
      REAL NYTFAC, MAXMIN,        NYTT, NYTTYM
      INTEGER FR(45,8 )
      IF(CLIMAT(JJ,2).GT.30.)CLIMAT(JJ,2)=30.
      MAXMIN= CLIMAT(JJ,2)-CLIMAT(JJ,3)
      TDAY=MAXMIN*DAYFAC+CLIMAT(JJ,3)
      TNYT=MAXMIN*NYTFAC+CLIMAT(JJ,3)
      TFACD=(TDAY-12.)/14.
      IF(TDAY.LT.12.)TFACD=0.
      TFACN=(TNYT-12.)/14.
      IF(TNYT.LT.12.)TFACN=0.
      DAYT=TFACD*DAYLNG
      DAYTYM=DAYT/24.
      NYTT=TFACN*(24.-DAYLNG)
      NYTTYM=NYTT/24.
       TAVG=(TDAY+TNYT)/2.
      DAYINC=DAYTYM+NYTTYM
   20 DAY=DAY+DAYINC
      I=(DAY*10.+5.)/10.
      IF(I.LT.1)I=1
      NEWDAY=I-IOLD
      IOLD=I
      RETURN
      END
```

```
MCKIN*TF.E
      SUBROUTINE PNET(LAI,CLIMAT,POPFAC,PLANTW,DAYTYM,NYTTYM,RSUBO,
     1PN,STRESS,TDAY,LYTRES,GSUBR,CO2,EFF,ROWSP,NMIN,LCONC)
C     THIS SUBROUTINE CALCULATES NET PHOTOSYNTHESIS(PN) PER DAY PER PLT.
C     CLIMAT IS RADIATION PER DAY
C     DAYTYM AND NYTTYM ARE LENGTHS OF DAY AND NIGHT IN PHYSIOLOGICAL
C     TIME
C     PTSRED IS THE FACTOR BY WHICH LEAF WILTING REDUCES THE RATE OF
C     PHOTOSYNTHESIS
C     RSUBL=COEFFICIENT FOR LIGHT RESPIRATION
C     RSUBO=COEFFICIENT FOR MAINTENANCE RESPIRATION
C     GSUBR=VEGETATION RESPIRATION COEFFICIENT
      DIMENSION CLIMAT(300,7),PCOT(200,9)
      REAL LAI,NYTTYM,LYTCPT,LYTRES
      INTEGER CO2,FR(45,8 )
      COMMON /COM/FR,DAY,I,JJ,PCOT,ISTSQR
      COMMON  STMWT,ROOTWT
      REAL LCONC,NMIN(5)
      FNIT=0.75+(0.25/0.012)*(LCONC-NMIN(1))
      IF(FNIT.LT..75)FNIT=0.75
      IF(FNIT.GT.1.0)FNIT=1.0
      Z=2.263-0.19859*(CLIMAT(JJ,6)-129.)+0.016169*((CLIMAT(JJ,6)-129.)*
     1*2)
      LYTCPT=1.0756*Z/ROWSP
      IF(LYTCPT.GE.1.)LYTCPT=1.
      IF(STRESS.LT.10.)PTSRED=.1
      IF(STRESS.LT.9.)PTSRED=.25
      IF(STRESS.LT.8.)PTSRED=.5
      IF(STRESS.LT.7.)PTSRED=.8
      IF(STRESS.LT.6.)PTSRED=1.
      WATTSM=CLIMAT(JJ,1)*.8942
      PSTAND=2.3908+1.37379*WATTSM-0.00054136*(WATTSM**2)
      PPLANT=PSTAND*LYTCPT*POPFAC*PTSRED*0.001
      PPLANT=PPLANT*1.06*EFF*FNIT
      CO2=CLIMAT(JJ,7)
      IF(CO2.EQ.1)PPLANT=PPLANT*1.405
C     CO2 IS A CO2 FERTILIZATION TRIGGER, WHEN EQUAL
C    1, PPLANT IS INCREASED 20% DUE TO 500 PPM CO2.
      RSUBL=0.0032125+0.0066875*TDAY
      LYTRES=RSUBL*PPLANT
      BMAIN=PLANTW*RSUBO*(DAYTYM+NYTTYM)
      PTS=PPLANT-LYTRES-BMAIN
      IF(PTS.LE..01)PTS=0.01
      PN=PTS/(1.+GSUBR)
      RETURN
      END
```

PROGRAM LISTING—Continued

MCKIN*TF.F

```
      SUBROUTINE QPREQZ(PQLEFD,PQLEFN,PQSTMD,PQSTMN,PQRTSD,PQRTSN,PQBOLD
     1,PQBOLN,PQRESN,PQFLR,PBOLL,NYTTYM,DAYTYM,PQBOLX,TFACD,TFACN,TOPRES
     2,PRES,RESADD,NEWDAY,LEFWT,SUMLEF,SUMSTM,SUMRTS,INOD,NONOD,
     3NOBR,FAGE,NVEG,NBRV,FRV,FAGV,NFL,ADD,NSTRES)
C     THIS SUBROUTINE CALCULATES THE PHOTOSYNTHATE REQUIRED FOR STANDARD
C     GROWTH BY EACH PART OF THE PLANT ON THE DATE BASED ON THE GROWTH
C     OF THE STANDARD PLANT ON THE SAME DAY
C     PQLEFD,PQLEFN, ETC.  ARE THE STANDARD REQUIREMENTS FOR DAY (D) AND
C     NIGHT (N) FOR LEAF (LEF) GROWTH, STEM (STM) GROWTH, ETC.
C     PQBOLD IS BOLL REQUIREMENT,PQRESN IS REQUIREMENT FOR REBUILDING
C     DEPLETED RESERVES,PQFLR IS THE METABOLIC COST OF A FLOWER
      REAL NYTTYM,LEFADD,LEFWT,          PCOT(200,9),PBOLL(60)
      INTEGER FRV(30,5),FAGV(30,5)
      INTEGER FR(45,8 ),FAGE(45,8 )
      COMMON /COM/FR,DAY,I,JJ,PCOT,ISTSQR
      COMMON  STMWT,ROOTWT
      XYN=NSTRES
      REDN=1.-0.4*XYN
      IF(REDN.LE.0.)REDN=0.
      LEFADD=ADD
      SUMLEF=SUMLEF+PCOT(I,5)*LEFADD
      SUMSTM=SUMSTM+PCOT(I,3)
      SUMRTS=SUMRTS+PCOT(I,1)
      QUAN=30000./20498.
      PCOT(I,5)=PCOT(I,5)*QUAN
      IF(I.GT.42)GO TO 15
      PCOT(I,3)=PCOT(I,3)*QUAN
      PCOT(I,1)=PCOT(I,1)*QUAN
      GO TO 16
   15 CONTINUE
      PCOT(I,3)=(.2+.06*STMWT)*QUAN
      PCOT(I,1)=(.02+.006*ROOTWT)*QUAN
   16 CONTINUE
      PQLEFN=PCOT(I,5)*NYTTYM*LEFADD
      PQLEFD=PCOT(I,5)*DAYTYM*LEFADD
      PQSTMD=PCOT(I,3)*DAYTYM
      PQSTMN=PCOT(I,3)*NYTTYM
      PQRTSD=PCOT(I,1)*    DAYTYM
      PQRTSN=PCOT(I,1)*    NYTTYM
      PQBOLD=0.
      PQBOLN=0.
      PQRESN=(TOPRES-PRES)*RESADD
      IF(I.LE.ISTSQR+ 28)GO TO 11
      DO 10 L=INOD,NONOD
      DO 10 M=1,NOBR
      NAGE=FAGE(L,M)- 28+    6
      IF(NAGE.LT.1) GO TO 10
      IF(FR(L,M).EQ.1)GO TO 8
      IF(FR(L,M).NE.2)GO TO 10
      IF(NAGE.GT.   60)GO TO 10
    8 CONTINUE
      PQBOLD=PBOLL(NAGE)*DAYTYM+PQBOLD
      PQBOLN=PBOLL(NAGE)*NYTTYM+PQBOLN
   10 CONTINUE
      DO 12 LV=3,NVEG
      DO 12 MV=1,NBRV
      NAGE=FAGV(LV,MV)- 28+    6
      IF(NAGE.LT.1) GO TO 12
      IF(FRV(LV,MV).EQ.1)GO TO 9
      IF(FRV(LV,MV).NE.2)GO TO 12
      IF(NAGE.GT.   60)GO TO 12
    9 CONTINUE
      PQBOLD=PBOLL(NAGE)*DAYTYM+PQBOLD
      PQBOLN=PQBOLN+PBOLL(NAGE)*NYTTYM
   12 CONTINUE
   11 CONTINUE
      PQBOLX=PQBOLD+PQBOLN
      IF(PQBOLX.LE.0)NFL=1
      IF(PQBOLX.GT.0)NFL=0
      IF(PQBOLX.LE.0.)PQBOLX=1.
      RETURN
      END
```

```
MCKIN*TF.G
      SUBROUTINE PQDAY2(STRESS,STRLMT,PQLEFD,PQSTMD,PQRTSD,PQBOLD,TRES,P
     1RES,PN,RESUFC,LEFWT,XTRES,TRNSLF,LEAFW,STMW,ROTW)
C     PQDAY2 COMPUTES THE PHOTOSYNTHATE USED FOR PLANT GROWTH FOR THE D*
      DIMENSION FR(45,8 )
      DIMENSION  PCOT(200,9)
      COMMON /COM/FR,DAY,I,JJ,PCOT,ISTSQR
      COMMON  STMWT,ROOTWT
      INTEGER XTRES
      REAL LEAFW
      REAL LEFWT
      LEAFW=LEFWT
      XTRES=0
      ROTW=ROOTWT
      STMW=STMWT
      TRESXX=PN*TRNSLF
      PN=PN-TRESXX
      IF(STRESS.GT.STRLMT) GO TO 41
      PREQ=PQLEFD+PQSTMD+PQBOLD+PQRTSD
      IF(PREQ.GT.PN)GO TO 40
C     NO STRESS ON PLANT
      TRES=PN-PREQ
   50 LEFWT=LEFWT+PQLEFD
      STMWT=STMWT+PQSTMD
      ROOTWT=ROOTWT+PQRTSD
      GO TO 200
   40 PAVAIL=PN+TRES+PRES*RESUFC
      XTRES=3
      IF(PREQ.GT.PAVAIL)GO TO 60
      IF(PREQ.GT.PN+TRES)GO TO 70
C     USES TEMPORARY  RESERVES AND PN ONLY
      TRES=PN+TRES-PREQ
      GO TO 50
   70 PRES=PRES-PREQ+PN+TRES
C     ALL TEMP. RESERVES ARE USED AS WELL AS SOME PERMANENT RESERVES
      TRES=0.
      GO TO 50
   41 PREQ=PQBOLD+PQRTSD
      IF(PREQ.GT.PN)GO TO 42
C     WATER STRESS ONLY
      TRES=PN-PREQ
   51 ROOTWT=ROOTWT+PQRTSD
      GO TO 200
   42 PAVAIL=PN+TRES+PRES*RESUFC
      XTRES=3
      IF(PREQ.GT.PAVAIL) GO TO 61
      IF(PREQ.GT.PN+TRES)GO TO 72
C     PLANT USES PN AND TEMP. RESERVES ONLY
      TRES=PN+TRES-PREQ
      GO TO 51
   72 PRES=PRES-PREQ+PN+TRES
C     PLANT DIPS INTO PERMANENT RESERVES
      TRES=0.
      GO TO 51
   61 TRES=0.
C     CARBOHYDRATE STRESS AND MOISTURE STRESS
      PRES=PRES-PRES*RESUFC
      F=PAVAIL/PREQ
C     F=RATIO OF AVAIL PN TO REQUIRED
      IF(F.LT..5)XTRES=3
      ROOTWT=ROOTWT+PQRTSD*F
      PQBOLD=PQBOLD*F
      GO TO 200
   60 TRES=0.
C     CARBOHYDRATE STRESS ONLY
      PRES=PRES-PRES*RESUFC
      F=PAVAIL/PREQ
      LEFWT=LEFWT+PQLEFD*F
      STMWT=STMWT+PQSTMD*F
      PQBOLD=PQBOLD*F
  200 CONTINUE
      PN=0.
      TRES=TRES+TRESXX
      RETURN
      END
```

MCKIN*TF.H

```
      SUBROUTINE PQNYTZ(PQLEFN,PQSTMN,PQRTSN,PQBOLN,PQRESN,PQFLR,TRES,
     1LEFWT,PRES,TOPRES,HISTD,LOSTD,XTRES,LEFSTF,POLYNA,RES
     1UFC,         PN,TOPRSF,STRESS,RFALL)
C     POLYNA (POLLINATE) IF GIVEN A VALUE SIGNALS THAT A BOLL MAY BE SET
C     PQNYTZ CALCULATES THE PHOTOSYNTHATE REQUIRED FOR PLANT PARTS FOR T
C     WILL OCCUR BASED ON THE CALCULATED CARBOHYDRATE STRESS OR LACK OF
C     NIGHT AND COMPUTES THE  WEIGHT GAINS. IT ALSO  COMPUTES WHETHER BO
C     IF A BLOOM IS PRESENT
      DIMENSION FR(45,8 )
      DIMENSION  PCOT(200,9)
      COMMON /COM/FR,DAY,I,JJ,PCOT,ISTSQR
      COMMON  STMWT,ROOTWT
      INTEGER POLYNA,XTRES
      REAL         LEFWT,LOSTD,LEFSTF
      TOPRES=STMWT*TOPRSF
      POLYNA=1.0
      XTRES=0
      PRESX=PRES
      TSLIMT=LEFWT*LEFSTF
      IF(TRES.GT.TSLIMT)TRES=TSLIMT
      IF(PRESX.LE.0.)PRESX=.001
      PREQ=PQLEFN+PQSTMN+PQRTSN+PQBOLN+PQRESN+PQFLR
      IF(PREQ.GT.TRES)GO TO 210
      TRES=TRES-PREQ
  230 ROOTWT=ROOTWT+PQRTSN
  250 LEFWT=LEFWT+PQLEFN
      STMWT=STMWT+PQSTMN
      PRES=PRES+PQRESN
      IF(PRES.GT.TOPRES)GO TO 231
  232 IF(TRES.LT.HISTD)GO TO 600
      POLYNA=1.
      GO TO 600
  231 TRES=TRES+PRES-TOPRES
      PRES=TOPRES
      GO TO 232
  210 PAVAIL=TRES+PRES*RESUFC
      IF(PREQ.GT.PAVAIL)GO TO 220
      PRES=PRES-PREQ+TRES
      TRES=0.
      ABC=(PRESX-PRES)/PRESX
      IF(ABC.LT.LOSTD)GO TO 221
      GO TO 230
  221 POLYNA=1.0
      GO TO 230
  220 TRES=0.
      PRES=PRES-PRES*RESUFC
      PREQ2=PREQ-PQRTSN
      IF(PREQ2.GT.PAVAIL)GO TO 240
      ROOTWT=ROOTWT+(PAVAIL-PREQ2)
      GO TO 250
  240 STQN=PQLEFN+PQSTMN+PQBOLN+PQRESN+PQFLR
      F=PAVAIL/STQN
      IF(F.LE..8)XTRES=1
      IF(F.LE..6)XTRES=2
      IF(F.LE..4)XTRES=3
      IF(F.LE..1)XTRES=4
      LEFWT=LEFWT+PQLEFN*F
      STMWT=STMWT+PQSTMN*F
      PQBOLN=PQBOLN*F
      PRES=PRES+PQRESN*F
  600 CONTINUE
      IF(RFALL.GT.0.5)POLYNA=0.
      RETURN
      END
```

MCKIN*TF.I

```
      SUBROUTINE NITR(RDEP,POM,EFN,TEMN,NMAX,NMIN,     ROWSP,PERN,POPPLT,
     1NPART,NSTRES,RESN,DREQN,DEFCIT,USE,LCONC,H2ODEF,H2OCAP,GBLOS,
     2LEFWT,COTXX,GRCOTX,R,JJK,FRVL,WS,WR)
      INTEGER FR(45,8 )
      DIMENSION PCOT(200,9)
      COMMON /COM/FR,DAY,I,JJ,PCOT,ISTSQR
      COMMON STMWT,ROOTWT
```

PROGRAM LISTING—Continued

```
      INTEGER FRVL
      REAL NMAX(5),NMIN(5),NPART(5),LCONC,LEFR,LEFWT,LEFRS,LEFR1
      DATA APPL/0./,WLEF/0./,WSTM/0./,WGRCOT/0./,WROT/0./,SCON/0./
      DATA BCON/0./,WCOTX/0./
C     NITROGEN SUBROUTINE FOR SIMCOT II
      BURR=0.
      DEFCIT=0.
      SEEDR=0.
      COTTON=(COTXX+GRCOTX)
      EXC=0.
      GRGR=COTTON-(WGRCOT+WCOTX)
      XN=.0515*20000./POPPLT
      NSTRES=0
      CW=ROWSP
      CD=30.48
      CL=(43560./ROWSP/POPPLT)*(30.48**2)
      VTOT=CW*CD*CL
      AW=(1./42.)*30.48*(JJ+7)
      AL=AW
      AD=(1./28.)*30.48*(JJ+7)
      IF(AW.GT.CW) AW=CW
      IF(AL.GT.CL)AL=CL
      IF(AD.GT.CD)AD=CD
      VPLT=AW*AD*AL
      PERN=(VPLT/VTOT)*74.5*POM/POPPLT
      PERN=PERN*(1.-(H2ODEF/(H2OCAP*10.))**2)
      TEMN=TEMN+(VTOT-VPLT)*74.5*POM/(POPPLT*VTOT)
C     CARDS INSERTED IF SIDE DRESSED, FORM AS FOLLOWS
      IF(JJ.EQ.40)APPL=66.7
      IF(APPL.LT.1.) GO TO 1
      IF(R.LT.0.05) GO TO 1
      TEMN=TEMN+(APPL*EFN*453.6)/POPPLT
      APPL=0.
    1 XNUP=XN
      USE=0.
      SUPR=1.
      SEEDR=NMAX(2)*COTTON*0.416-NPART(2)
      BURR=NMAX(3)*COTTON*0.278-NPART(3)
   22 LEFR=NMAX(1)*LEFWT-NPART(1)
      STMR=NMAX(4)*STMWT-NPART(4)
      ROTR=NMAX(4)*ROOTWT-NPART(5)
      IF(LEFR.LT.0.) LEFR=0.
      IF(SEEDR.LT.0.) SEEDR=0.
      IF(BURR.LT.0.) BURR=0.
      IF(STMR.LT.0.) STMR=0.
      IF(ROTR.LT.0.) ROTR=0.
      DREQN=SEEDR+LEFR+BURR+STMR+ROTR
      SEEDR1=NMAX(2)*GRGR*0.416
      LEFR1=NMAX(1)*(LEFWT-WLEF)
      IF(LEFR1.LT.0)LEFR1=0.
C     BURMIN=MIN. NITR. REQ FOR BUR GROWTH
      BURMIN=NMIN(3)*GRGR*0.278
      BURR1=(NMAX(3)-NMIN(3))*GRGR*0.278
      STMR1=NMAX(4)*(STMWT-WSTM)
      ROTR1=NMAX(4)*(ROOTWT-WROT)
      BOL1=BURMIN+SEEDR1
      IF(BOL1.LE.0.) BOL1=0.000001
      REQ1=LEFR1+SEEDR1+BURR1+STMR1+ROTR1+BURMIN
      IF(H2ODEF.GT.0.5*H2OCAP*10.)XNUP=XN*0.9
      IF(H2ODEF.GT.0.6*H2OCAP*10.)XNUP=XN*0.8
      IF(H2ODEF.GT.0.8*H2OCAP*10.)XNUP=XN*0.6
      IF(H2ODEF.GT.0.9*H2OCAP*10.)XNUP=XN*0.4
      IF(H2ODEF.GT.95*H2OCAP*10.)XNUP=XN*0.2
      IF(PERN+TEMN.LT.XNUP) XNUP=PERN+TEMN
      XNUP1=XNUP
      IF( REQ1.GT.XNUP)GO TO 2
      IF(REQ1.LE.0.0) REQ1=0.
      IF(REQ1.LT.XNUP)GO TO 10
      XNUP=REQ1
      GO TO 3
    2 IF(XNUP.LT.BOL1   ) GO TO 6
      SUPR=(XNUP-BOL1   )/(REQ1-BOL1   )
      IF(SUPR.LT..000001)SUPR=.000001
      NSTRES=1
    3 IF(PERN.GE.XNUP) GO TO 4
      IF(PERN+TEMN.GE.XNUP) GO TO 5
      IF(PERN+TEMN.LT.BOL1   ) GO TO 6
```

PROGRAM LISTING—Continued

```
      SUPR1=(PERN+TEMN-BOL1   )/(REQ1-BOL1   )
      IF(SUPR1.LT.SUPR) SUPR=SUPR1
      IF(SUPR.LT..000001)SUPR=.000001
      NSTRES=1
    5 TEMN=TEMN-XNUP+PERN
      IF(TEMN.LT.0.0) TEMN=0.
    4 NPART(1)=LEFR1*SUPR+NPART(1)
      IF(NPART(1).LT..0001) NPART(1)=.0001
      NPART(2)=NPART(2)+SEEDR1
      IF(NPART(2).LT..0001) NPART(2)=.0001
      NPART(3)=NPART(3)+BURMIN
      NPART(3)=NPART(3)+BURR1*SUPR
      IF(NPART(3).LT..0001) NPART(3)=.0001
      NPART(4)=STMR1*SUPR+NPART(4)
      IF(NPART(4).LT..0001) NPART(4)=.0001
      NPART(5)=ROTR1*SUPR+NPART(5)
      IF(NPART(5).LT..0001) NPART(5)=.0001
      GO TO 20
    6 DEFCIT=BOL1   -XNUP
      IF(RESN.GT.0.) GO TO 7
      NSTRES=3
      IF(DEFCIT/BOL1.GT.0.67) NSTRES=4
      NPART(2)=NPART(2)+XNUP*SEEDR1/BOL1
      IF(NPART(2).LT..0001) NPART(2)=.0001
      NPART(3)=NPART(3)+XNUP*BURMIN/BOL1
      IF(NPART(3).LT..0001) NPART(3)=.0001
      TEMN=TEMN-XNUP+PERN
      IF(TEMN.LT.0.) TEMN=0.
      GO TO 20
    7 NPART(2)=NPART(2)+SEEDR1
      IF(NPART(2).LT..0001) NPART(2)=.0001
      NPART(3)=NPART(3)+BURMIN
      IF(NPART(3).LT..0001) NPART(3)=.0001
      NPART(1)=NPART(1)-DEFCIT*LEFRS/RESN
      IF(NPART(1).LT..0001) NPART(1)=.0001
      NPART(4)=NPART(4)-DEFCIT*STMRS/RESN
      IF(NPART(4).LT..0001) NPART(4)=.0001
      NPART(5)=NPART(5)-DEFCIT*ROTRS/RESN
      IF(NPART(5).LT..0001) NPART(5)=.0001
      TEMN=TEMN-XNUP+PERN
      NSTRES=2
      USE=(DEFCIT-RESN)/BOL1
      IF(USE.GT..1)NSTRES=3
      IF(USE.GT.0.90)NSTRES=4
      IF(TEMN.LE.XNUP) TEMN=0.
      GO TO 20
   10 IF(DREQN.GT.REQ1) EXC=XNUP1-REQ1
      IF(DREQN.LT.XNUP1.AND.EXC.GT.0.) EXC=DREQN-REQ1
      TEMN=TEMN-EXC-REQ1+PERN
      IF(TEMN.LT.0.) TEMN=0.
      IF((DREQN-SEEDR).LE.0.0) GO TO 20
      NPART(2)=NPART(2)+SEEDR1
      IF(NPART(2).LT..0001) NPART(2)=.0001
      NPART(1)=NPART(1)+EXC*LEFR/(DREQN-SEEDR)+LEFR1
      IF(NPART(1).LT..0001) NPART(1)=.0001
      NPART(3)=NPART(3)+EXC*BURR/(DREQN-SEEDR)+BURR1
      IF(NPART(3).LT..0001) NPART(3)=.0001
      NPART(4)=NPART(4)+EXC*STMR/(DREQN-SEEDR)+STMR1
      IF(NPART(4).LT..0001) NPART(4)=.0001
      NPART(5)=NPART(5)+EXC*ROTR/(DREQN-SEEDR)+ROTR1
      IF(NPART(5).LT..0001) NPART(5)=.0001
20    STMWT=STMWT+WS
      ROOTWT=ROOTWT+WR
      LEFRS=NPART(1)-NMIN(1)*LEFWT
      STMRS=NPART(4)-NMIN(4)*STMWT
      ROTRS=NPART(5)-NMIN(4)*ROOTWT
      IF(COTXX+GRCOTX.LT.0.01) GO TO 21
      SCON=NPART(2)-GBLOS*NPART(2)/COTTON
      BCON=NPART(3)/(COTTON*0.278)
      IF(BCON.LT..0001) BCON=.0001
      NPART(2)=NPART(2)-GBLOS*NPART(2)/COTTON
      IF(NPART(2).LT..0001) NPART(2)=.0001
      NPART(3)=NPART(3)-GBLOS*NPART(3)/COTTON
      IF(NPART(3).LT..0001) NPART(3)=.0001
   21 STCON=NPART(4)/STMWT
      IF(STCON.LT..0001) STCON=.0001
      RCON=NPART(5)/ROOTWT
```

```
      LCONC=NPART(1)/LEFWT
      IF(LCONC.LT..0001) LCONC=.0001
      IF(LEFRS.LT.0.) LEFRS=0.
      IF(STMRS.LT.0.) STMRS=0.
      IF(ROTRS.LT.0.) ROTRS=0.
      RESN=LEFRS+STMRS+ROTRS
      IF(RESN.LT.0.)RESN=0.
      IF(JJ.NE.JJK)GO TO 80
      WRITE(6,50)LCONC,SCON,BCON,STCON,RCON,NSTRES
50    FORMAT(' ',' CONCENTRATIONS ',5F7.4,'  NSTRES=',I2)
      WRITE(6,75)NPART
75    FORMAT(' ',' NPART(1-5) ',5F8.4)
80    CONTINUE
   77 WLEF=LEFWT
      WGRCOT=GRCOTX
      WSTM=STMWT-WS
      WCOTX=COTXX
      WROT=ROOTWT-WR
      STMWT=STMWT-WS
      ROOTWT=ROOTWT-WR
      RETURN
      END
```

MCKIN*CLMCOT.J

```
      SUBROUTINE PLTMAP(PBOLL,WTBOLL,TAVG,NEWDAY,PQBOLN,PQBOLD,PQBOLX,
     1XTRES,NOBR1,NONOD,BOLLST,SQLOST,COTXX,GRCOTX,ROWSP,PQFLR,POLYNA,
     2FAGE,INOD,NOBR,POPPLT,NUMGRN,NUMOPN,NVEG,NBRV,FRV,FAGV,WTBOLV,NV
     3,BLOOM,LEAFW,LEFWT,NFL,CLIMAT, STMW,ROTW,GBLOS,WLOST,NSTRES,JJK)
      DIMENSION CLIMAT(300,7)
      INTEGER JK(45,8)/360*0/,JKV(30,5)/150*0/
      DIMENSION WLOST(3)
      DIMENSION STEMW(200),ROOTW(200)
      COMMON /COM/FR,DAY,I,JJ,PCOT,ISTSQR
      COMMON STMWT,ROOTWT
      REAL LEAFW
      REAL LEFWT
      REAL LEAFWT(200)/200*0./
      INTEGER SQLOST,BOLLST,BLOOM
      INTEGER FRV(30,5),FAGV(30,5)
      DATA AVTEMP/0./,ISQ/0/,TMAIN/0./
      REAL   TMPV(30)/30*0./,DSV(30)/30*0./
      INTEGER  NTLV(30)/30*0/
      REAL       TBRV(30)/30*0./,WTBOLV(30,5)
      INTEGER  XTRES,FR(45,8 ),NTL(45)/45*0/,FAGE(45,8 ),POLYNA
      REAL       PCOT(200,9),PBOLL(60),WTBOLL(45,8 ),DSQ(45)/45*0./,
     1TAVL(45)/45*0./,T(45)/45*0./
      IF(NSTRES.EQ.1)NSTRES=0
      ROOTW(JJ)=ROOTWT-ROTW
      LAST=0
      GBLOS=0.
      STEMW(JJ)=STMWT-STMW
      IF(JJ.LE.24)GO TO 8000
      STMWT=STMWT-STEMW(JJ-24)
      ROOTWT=ROOTWT-ROOTW(JJ-24)
      WLOST(1)=STEMW(JJ-24)
      WLOST(2)=ROOTW(JJ-24)
8000  CONTINUE
      PQFLR=0.
      XTRES=0
      LEAFWT(JJ)=LEFWT-LEAFW
      XM=0.0529-(2.147*POPPLT)/(10.**7)
      NOBR=2.0+XM*ROWSP+1.
C     THE '+1.' IS ADDED TO NOBR TO ACCOUNT FOR THE MAIN STEM NODE
C     WHERE THE BRANCH IS ATTACHED.
      IF(ISQ.EQ.1)GO TO 3
      IF(I.GE.31)GO TO 1
C     AVTEMP IS ACCUMULATED AVG TEMP FOR FIRST 31 DAYS
      AVTEMP=((JJ-1)*AVTEMP+TAVG)/JJ
      RETURN
    1 IF(AVTEMP.LE.27.)GO TO 2
      ISQ=1
      ISTSQR=I   +(AVTEMP-27.)*3.
      INOD=6.+1.333*(AVTEMP-27.)
      NONOD=INOD
```

PROGRAM LISTING—Continued

```
          GO TO 3
        2 ISTSQR=I
          ISQ=1
          INOD=7
          NONOD=INOD
        3 IF(I.GE.ISTSQR)GO TO 4
          RETURN
        4 IF(I.GT.ISTSQR)GO TO 5
          NVEG=30
          NBRV=4.5-0.00002895*POPPLT+1
          FRLST=0
          FRLSTV=0
          IF(NBRV.LT.1)NBRV=1
          TV=I+2.5
          NV=1
          TBRV(1)=I+6.0
          DSV(1)=JJ
          DO 6 L=1,INOD
          IF(LAST.EQ.1)GO TO 6
          FR(L,1)=4
          FAGE(L,1)=1
        6 CONTINUE
          TMAIN=I   +2.5
          T(INOD)=I   +6.0
          DSQ(INOD)=JJ
          NONOD=INOD
          NOBR1=2
          IF(LAST.EQ.1)GO TO 5
          FR(INOD,2)=1
          FRV(1,1)=4
5         IF(NEWDAY.EQ.0)GO TO 7
          COTXX=0.
          GRCOTX=0.
          NUMGRN=0
          NUMOPN=0
          BLOOM=0.
7         BOLINC      =(PQBOLD+PQBOLN)/PQBOLX
          IF(NFL.EQ.1)GO TO 901
          IF(BOLINC      .LE..85)XTRES=1
          IF(BOLINC      .LE..6)XTRES=2
          IF(BOLINC      .LE..35)XTRES=3
          IF(BOLINC      .LE..2)XTRES=4
901       CONTINUE
          IF(NEWDAY.EQ.0)GO TO 630
          DO 610 L=1,NONOD
          DO 610 M=1,NOBR1
          IF(FR(L,M).EQ.0) GO TO 610
          FAGE(L,M)=FAGE(L,M)+1
          IF(FR(L,M).NE.1)GO TO 8
          IF(FAGE(L,M).NE.  28)GO TO 8
          IF(LAST.EQ.1)GO TO 8
          PQFLR=PQFLR+PCOT(I,7)
          IF(POLYNA.EQ.1)GO TO 9
          FR(L,M)=4
          BLOOM=BLOOM+1.
          GO TO 8
        9 FR(L,M)=2
        8 CONTINUE
          IF(FR(L,M).NE.2) GO TO 12
          IF(FAGE(L,M).NE.76) GO TO 10
          IF(LAST.EQ.1)GO TO 10
          FR(L,M)=3
       10 CONTINUE
          IF(JJ.EQ.JJK.AND.LAST.EQ.1.AND.FR(L,M).EQ.2.AND.FAGE(L,M).LT.28)
         1FAGE(L,M)=28
          NAGE=FAGE(L,M)- 28
          IF(NAGE.LT.1)GO TO 610
          IF(NAGE.GT.60   )NAGE=60
          IF(FR(L,M).NE.2) GO TO 12
          NUMGRN=NUMGRN+1
          WTBOLL(L,M)=WTBOLL(L,M)+PBOLL(NAGE)*BOLINC
          GRCOTX=GRCOTX+WTBOLL(L,M)
          GO TO 610
       12 IF(FR(L,M).NE.3) GO TO 610
          NUMOPN=NUMOPN+1
          COTXX=COTXX+WTBOLL(L,M)
      610 CONTINUE
```

```
      DO 710 LV=3,NVEG
      DO 710 MV=1,NBRV
      IF(FRV(LV,MV).EQ.0) GO TO 710
      FAGV(LV,MV)=FAGV(LV,MV)+1
      IF(FRV(LV,MV).NE.1) GO TO 78
      IF(FAGV(LV,MV).NE. 28)GO TO 78
      IF(LAST.EQ.1)GO TO 78
      IF(POLYNA.EQ.1) GO TO 79
      PQFLR=PQFLR+PCOT(I,7)
      FRV(LV,MV)=4
      BLOOM=BLOOM+1.
      GO TO 78
   79 FRV(LV,MV)=2
   78 CONTINUE
      IF(FRV(LV,MV).NE.2) GO TO 82
      IF(FAGV(LV,MV).NE.76) GO TO 80
      IF(LAST.EQ.1)GO TO 80
      FRV(LV,MV)=3
   80 CONTINUE
      IF(JJ.EQ.JJK.AND.LAST.EQ.1.AND.FRV(LV,MV).EQ.2.AND.FAGV(LV,MV).LT.
     128)FAGV(LV,MV)=28
      NAGE=FAGV(LV,MV)- 28
      IF(NAGE.LT.1) GO TO 710
      IF(NAGE.GT.60   )NAGE=60
      IF(FRV(LV,MV).NE.2) GO TO 82
      NUMGRN=NUMGRN+1
      WTBOLV(LV,MV)=WTBOLV(LV,MV)+PBOLL(NAGE)*BOLINC
      GRCOTX=GRCOTX+WTBOLV(LV,MV)
      GO TO 710
   82 IF(FRV(LV,MV).NE.3) GO TO 710
      NUMOPN=NUMOPN+1
      COTXX=COTXX+WTBOLV(LV,MV)
  710 CONTINUE
  630 CONTINUE
      IF(JJ.EQ.JJK.AND.LAST.EQ.1)I=TMAIN
      IF(I.LT.TMAIN)GO TO 14
      TMAIN=TMAIN+2.5
      NONOD=NONOD+1
      T(NONOD)=I   +6.0
      DSQ(NONOD)=JJ
      IF(LAST.EQ.1)GO TO 14
      FR(NONOD,1)=4
      FR(NONOD,2)=1
C       BURNING PINHEAD SQUARES
      IF(CLIMAT(JJ,1).GE.700.)FR(NONOD,2)=4
      FAGE(NONOD 1)=1
   14 CONTINUE
      DO 15 L=INOD,NONOD
      TAVL(L)=(TAVL(L)*(JJ-DSQ(L))+TAVG)/(JJ-DSQ(L)+1)
      IF(I.LT.T(L))GO TO 15
      IF(NTL(L).EQ.1)GO TO 20
      T(L)=T(L)+0.333*(30.-TAVL(L))
      NTL(L)=1
   20 IF(I.LT.T(L))GO TO 15
      NTL(L)=0
      TAVL(L)=0.
      DSQ(L)=JJ
      ICNOD=0
      DO 16 M=1,NOBR
      IF(ICNOD.GT.0)GO TO 16
      IF(FR(L,M).GT.0) GO TO 16
      ICNOD=1
      T(L)=I+6.0
      IF(LAST.EQ.1)GO TO 17
      FR(L,M)=1
C       BURNING PINHEAD SQUARES
      IF(CLIMAT(JJ,1).GE.700.)FR(L,M)=4
      FAGE(L,M)=1
17    CONTINUE
      IF(L.NE.INOD) GO TO 16
      NOBRI=NOBRI+1
   16 CONTINUE
   15 CONTINUE
      IF(NV.GE.NVEG) GO TO 90
      IF(JJ.EQ.JJK.AND.LAST.EQ.1)I=TV
      IF(I.LT.TV) GO TO 90
      TV=TV+2.5
```

PROGRAM LISTING—Continued

```
      NV=NV+1
      IF(LAST.EQ.1)GO TO 900
      FRV(NV,1)=4
900   CONTINUE
      IF(NV.LT.3)GO TO 802
      IF(LAST.EQ.1)GO TO 90
      FRV(NV,2)=1
C      BURNING PINHEAD SQUARES
      IF(CLIMAT(JJ,1).GE.700.)FRV(NV,2)=4
      TBRV(NV)=I+6.0
800   FAGV(NV,1)=1
   90 CONTINUE
      IF(NV.LT.3)GO TO 802
      DO 95 LV=3,NV
      TMPV(LV)=(TMPV(LV)*(JJ-DSV(LV))+TAVG)/(JJ-DSV(LV)+1.)
      IF(I.LT.TBRV(LV)) GO TO 95
      IF(NTLV(LV).EQ.1) GO TO 97
      NTLV(LV)=1
      TBRV(LV)=TBRV(LV)+0.333*(30.-TMPV(LV))
   97 IF(I.LT.TBRV(LV)) GO TO 95
      TBRV(LV)=TBRV(LV)+6.0
      NTLV(LV)=0
      TMPV(LV)=0.
      DSV(LV)=JJ
      IVNOD=0
      DO 96 MV=1,NBRV
      IF(IVNOD.GT.0) GO TO 96
      IF(FRV(LV,MV).GT.0) GO TO 96
      IVNOD=1
      IF(LAST.EQ.1)GO TO 95
      FRV(LV,MV)=1
C      BURNING PINHEAD SQUARES
      IF(CLIMAT(JJ,1).GE.600.)FRV(LV,MV)=4
      FAGV(LV,MV)=1
   96 CONTINUE
   95 CONTINUE
802   CONTINUE
      SQLOST=0.
      BOLLST=0.
      XYN=NSTRES
      TMAIN=TMAIN+1.33*XYN/4.
      TV=TV+1.33*XYN/3.
      IF(LAST.EQ.1)GO TO 1000
      DO 1002 L=INOD,NONOD
      DO 1002 M=1,NOBR
      IF(FR(L,M).EQ.5.AND.JK(L,M).EQ.JJ)GO TO 1001
      IF(FR(L,M).EQ.6.AND.JK(L,M).EQ.JJ)GO TO 1003
      GO TO 1002
1001  FR(L,M)=4
      SQLOST=SQLOST+1
      GO TO 1002
1003  FR(L,M)=4
      BOLLST=BOLLST+1
      GRCOTX=GRCOTX-WTBOLL(L,M)
      GBLOS=GBLOS+WTBOLL(L,M)
      WTBOLL(L,M)=0.
1002  CONTINUE
1000  CONTINUE
      IF(LAST.EQ.1)GO TO 2000
      DO 2002 MV=1,NBRV
      DO 2002 LV=1,NVEG
      IF(FRV(LV,MV).EQ.5.AND.JKV(LV,MV).EQ.JJ)GO TO 2001
      IF(FRV(LV,MV).EQ.6.AND.JKV(LV,MV).EQ.JJ)GO TO 2003
      GO TO 2002
2001  FRV(LV,MV)=4
      SQLOST=SQLOST+1
      GO TO 2002
2003  FRV(LV,MV)=4
      BOLLST=BOLLST+1
      GRCOTX=GRCOTX-WTBOLV(LV,MV)
      GBLOS=GBLOS+WTBOLV(LV,MV)
      WTBOLV(LV,MV)=0.
2002  CONTINUE
2000  CONTINUE
      IF(XTRES.LE.0..AND.NSTRES.EQ.0)GO TO 125
      DO 114 L=INOD,NONOD
      T(L)=T(L)+1.33*XYN/4.
```

PROGRAM LISTING—Continued

```
          IF(XTRES.EQ.4)T(L)=T(L)+1.50
          IF(XTRES.EQ.3)T(L)=T(L)+1.20
          IF(XTRES.EQ.2)T(L)=T(L)+0.60
          IF(XTRES.EQ.1)T(L)=T(L)+0.20
          IF(LAST.EQ.1)GO TO 1140
          DO 114 M=1,NOBR
          IF(FR(L,M).NE.1)GO TO 119
          IF(XTRES.EQ.0)GO TO 119
          GO TO (109,110,111,112),XTRES
   109    IF(FAGE(L,M).GE.12..AND.FAGE(L,M).LE.12.)GO TO 113
          GO TO 114
   110    IF(FAGE(L,M).GE.12..AND.FAGE(L,M).LE.12.)GO TO 113
          GO TO 114
   111    IF(FAGE(L,M).GE.9.0.AND.FAGE(L,M).LE.12.)GO TO 113
          GO TO  114
   112    IF(FAGE(L,M).GE.8.0.AND.FAGE(L,M).LE.13.)GO TO 113
          GO TO  114
   113    CONTINUE
          FR(L,M)=5
          JK(L,M)=JJ+8
          GO TO  114
      119 CONTINUE
          IF(NSTRES.EQ.0)GO TO 114
          GO TO (114,116,117,118),NSTRES
   118    IF(FR(L,M).EQ.2.AND.FAGE(L,M).LE.38)GO TO 120
          IF(FR(L,M).EQ.1.AND.FAGE(L,M).LE.6)GO TO 114
   117    IF(FR(L,M).EQ.2.AND.FAGE(L,M).LE.33)GO TO 120
   116    IF(FR(L,M).EQ.1.AND.FAGE(6,M).LE.3)GO TO 114
          GO TO 114
   120    CONTINUE
          FR(L,M)=6
          JK(L,M)=JJ+8
      114 CONTINUE
   1140   CONTINUE
          DO 214 LV=1,NVEG
          TBRV(LV)=TBRV(LV)+1.33*XYN/3.
          IF(XTRES.EQ.4)TBRV(LV)=TBRV(LV)+1.50
          IF(XTRES.EQ.3)TBRV(LV)=TBRV(LV)+1.20
          IF(XTRES.EQ.2)TBRV(LV)=TBRV(LV)+0.60
          IF(XTRES.EQ.1)TBRV(LV)=TBRV(LV)+0.20
          IF(LAST.EQ.1)GO TO 2140
          DO 214 MV=1,NBRV
          IF(FRV(LV,MV).NE.1)GO TO 219
          IF(XTRES.EQ.0)GO TO 219
          GO TO (209,210,211,212),XTRES
   209    IF(FAGV(LV,MV).GE.12..AND.FAGV(LV,MV).LE.12.)GO TO 213
          GO TO 214
   210    IF(FAGV(LV,MV).GE.12..AND.FAGV(LV,MV).LE.12.)GO TO 213
          GO TO 214
   211    IF(FAGV(LV,MV).GE.9.0.AND.FAGV(LV,MV).LE.12.)GO TO 213
          GO TO  214
   212    IF(FAGV(LV,MV).GE.8.0.AND.FAGV(LV,MV).LE.13.)GO TO 213
          GO TO  214
   213    CONTINUE
          FRV(LV,MV)=5
          JKV(LV,MV)=JJ+8
          GO TO 214
   219    CONTINUE
          IF(NSTRES.EQ.0)GO TO 214
          GO TO (214,216,217,218),NSTRES
   218    IF(FRV(LV,MV).EQ.2.AND.FAGV(LV,MV).LE.38)GO TO 220
          IF(FRV(LV,MV).EQ.1.AND.FAGV(LV,MV).LE.6)GO TO 214
          GO TO 214
   217    IF(FRV(LV,MV).EQ.2.AND.FAGV(LV,MV).LE.33)GO TO 220
   216    IF(FRV(LV,MV).EQ.1.AND.FAGV(LV,MV).LE.3)GO TO 214
          GO TO  214
   220    CONTINUE
          FRV(LV,MV)=6
          JKV(LV,MV)=JJ+8
   214    CONTINUE
   2140   CONTINUE
          IF(XTRES.EQ.0)GO TO 126
          GO TO (130,131,132,133),XTRES
   133    TMAIN=TMAIN+1.0
          TV=TV+1.0
          GO TO 126
     ?    TMAIN=TMAIN+.7
```

PROGRAM LISTING--Continued

```
      TV=TV+.7
      GO TO 126
 131  TMAIN=TMAIN+.4
      TV=TV+.4
      GO TO 126
 130  TMAIN=TMAIN+0.0
      TV=TV+0.0
  126 CONTINUE
  125 CONTINUE
      IF(JJ.LE.71)GO TO 2141
      LEFWT=LEFWT-LEAFWT(JJ-70)
      WLOST(3)=LEAFWT(JJ-70)
 2141 CONTINUE
      RETURN
      END
```

```
@DATA,L   COTDA.
DATA006-RLIB69      01/16-16:06:20
          DATA FOR SIMCOT II.THE DATA CONSISTS OF SIX SECTIONS,FOUR OF WHICH ARE
          REQUIRED BY THE PROGRAM FOR PROPER OPERATION.THE OTHER TWO SECTIONS
          MUST BE SUPPLIED BY THE USER TO SIMULATE HIS CROP AT HIS LOCATION.THE
          FOLLOWING DATA ARE AN EXAMPLE WHICH THE USER CAN USE TO CONSTRUCT HIS
          OWN DATA FILE.
          ********************************************************************************
          PROGRAM SUPPLIED DATA.
          12345678901234567890123456789012345678901234567890123456789012345678901234567890
          [  PQRTS ][ PQSTM   ][  PQLEF  ][PQFLR    ][NOT USED]
           .020        .20        .20        .00        .10
           .020        .20        .20        .00        .05
           .020        .20        .20        .00        .20
           .020        .20        .20        .00        .30
           .020        .20        .20        .00        .40
           .020        .20        .20        .00        .48
           .020        .20        .20        .00        .56
           .020        .20        .20        .00        .64
           .020        .20        .20        .00        .72
           .020        .20        .20        .00        .80
           .030        .30        .30        .00        .92
           .030        .30        .30        .00       1.04
           .030        .30        .30        .00       1.16
           .030        .30        .30        .00       1.28
           .030        .30        .30        .00       1.40
           .050        .50        .32        .00       1.56
           .050        .50        .32        .00       1.72
           .050        .50        .32        .00       1.88
           .050        .50        .32        .00       2.04
           .050        .50        .32        .00       2.20
           .080        .80        .48        .00       2.46
           .080        .80        .48        .00       2.72
           .080        .80        .48        .00       2.98
           .080        .80        .48        .00       3.24
           .080        .80        .48        .00       3.50
           .060        .60        .40        .00       3.70
           .060        .60        .40        .00       3.90
           .060        .66        .40        .00       4.10
           .060        .60        .40        .00       4.30
           .060        .60        .40        .00       4.50
           .080        .80        .60        .00       4.76
           .080        .80        .60        .00       5.02
           .080        .80        .60        .00       5.28
           .080        .80        .60        .00       5.54
           .080        .80        .60        .00       5.80
           .080        .80        .60        .00       5.80
           .080        .80        .60        .00       5.80
           .090        .80        .60        .00       5.80
           .080        .80        .60        .00       5.80
           .080        .80        .60        .00       5.80
           .080        .80        .60        .50       5.80
          ********************************************************************************
          PROGRAM SUPPLIED DATA .THE FOLLOWING IS THE PBOLL DATA.
           .040 .040 .050 .060 .070 .100 .225 .225 .225 .225 .225 .225 .225 .225 .225 .225
           .225 .225 .225 .225 .225 .225 .225 .225 .225 .225 .215 .200 .195 .190 .175 .160
           .150 .130 .120 .110 .100 .095 .080 .075 .070 .060 .050 :040 .035 .030 .027 .020
           .015 .010 .009 .007 .005 .004 .002 .001
          ********************************************************************************
          USER SUPPLIED DATA.SUPPLY TITLE.
                WEATHER FOR COPIAH COUNTY,MISS. ,1972
          SUPPLY NUMBER OF DAYS OF WEATHER DATA IN DATA.
                 187
          ********************************************************************************
          SUPPLY WEATHER DATA FOR GROWING SEASON.
          12345678901234567890123456789012345678901234567890123456789012345678901234567890
          [  SOLAR ][  TMAX   ][  TMIN   ][  RFALL ][  EVAP   ][ DAY NO ][   CO2 T ]
              138.00      80.00      54.00                      .06      119.00
              468.00      80.00      54.00                      .01      120.00
              443.00      80.00      54.00                      .15      121.00
              405.00      86.00      57.00                      .20      122.00
              208.00      78.00      60.00       1.53           .20      123.00
              608.00      79.00      59.00         69           .06      124.00
              698.00      77.00      47.00                      .25      125.00
              589.00      80.00      52.00                      .22      126.00
              484.00      81.00      50.00                      .19      127.00
              584.00      76.00      64.00        .10           .18      128.00
              584.00      81.00      65.00        .58           .04      129.00
              658.00      76.00      60.00                      .15      130.00
              631.00      74.00      53.00                      .22      131.00
              446.00      70.00      66.00                      .22      132.00
```

PROGRAM LISTING—Continued

000080	212.00	69.00	64.00	.06	.19	133.00
000081	658.00	81.00	60.00	.80	.09	134.00
000082	663.00	80.00	60.00		.19	135.00
000083	698.00	79.00	56.00	.02	.28	136.00
000084	647.00	86.00	54.00		.28	137.00
000085	547.00	82.00	60.00		.27	138.00
000086	656.00	77.00	55.00		.21	139.00
000087	661.00	78.00	58.00		.26	140.00
000088	645.00	87.00	56.00		.33	141.00
000089	657.00	87.00	56.00		.28	142.00
000090	641.00	91.00	61.00		.29	143.00
000091	648.00	90.00	65.00		.25	144.00
000092	635.00	90.00	73.00		.30	145.00
000093	663.00	88.00	61.00		.27	146.00
000094	596.00	90.00	59.00		.33	147.00
000095	596.00	88.00	62.00		.25	148.00
000096	596.00	89.00	60.00		.29	149.00
000097	395.00	90.00	61.00		.24	150.00
000098	692.00	89.00	59.00		.16	151.00
000099	638.00	81.00	57.00		.32	152.00
000100	706.00	86.00	50.00		.25	153.00
000101	707.00	79.00	46.00		.24	154.00
000102	690.00	90.00	54.00		.28	155.00
000103	685.00	89.00	55.00		.26	156.00
000104	630.00	91.00	54.00		.28	157.00
000105	643.00	91.00	60.00		.28	158.00
000106	515.00	97.00	65.00		.26	159.00
000107	532.00	94.00	65.00		.32	160.00
000108	396.00	93.00	62.00		.23	161.00
000109	493.00	92.00	69.00		.20	162.00
000110	515.00	90.00	65.00		.23	163.00
000111	623.00	90.00	68.00	.04	.22	164.00
000112	410.00	92.00	68.00		.27	165.00
000113	301.00	91.00	69.00	.05	.17	166.00
000114	396.00	92.00	66.00	.13	.11	167.00
000115	352.00	89.00	70.00	.24	.11	168.00
000116	656.00	90.00	70.00	.07	.09	169.00
000117	648.00	91.00	71.00		.23	170.00
000118	652.00	89.00	69.00		.28	171.00
000119	657.00	95.00	65.00		.33	172.00
000120	549.00	91.00	68.00	.34	.36	173.00
000121	326.00	92.00	61.00		.20	174.00
000122	301.00	90.00	62.00	.23	.17	175.00
000123	545.00	92.00	71.00		.10	176.00
000124	241.00	89.00	68.00		.22	177.00
000125	584.00	93.00	72.00	.91	.12	178.00
000126	607.00	94.00	73.00		.26	179.00
000127	554.00	93.00	75.00		.36	180.00
000128	215.00	90.00	70.00		.29	181.00
000129	370.00	94.00	68.00	1.53	.08	182.00
000130	602.00	92.00	68.00	.19	.21	183.00
000131	635.00	93.00	73.00		.26	184.00
000132	260.00	93.00	69.00	.11	.28	185.00
000133	278.00	89.00	67.00	.26	.19	186.00
000134	659.00	77.00	67.00	.15	.11	187.00
000135	669.00	81.00	59.00		.25	188.00
000136	692.00	85.00	57.00		.25	189.00
000137	508.00	86.00	55.00		.23	190.00
000138	611.00	89.00	59.00		.18	191.00
000139	551.00	88.00	65.00		.19	192.00
000140	614.00	91.00	63.00		.22	193.00
000141	630.00	92.00	66.00		.27	194.00
000142	568.00	85.00	63.00	.61	.27	195.00
000143	533.00	89.00	67.00	.58	.27	196.00
000144	461.00	90.00	65.00		.24	197.00
000145	598.00	93.00	70.00		.20	198.00
000146	499.00	88.00	68.00	.83	.28	199.00
000147	627.00	90.00	67.00	.45	.20	200.00
000148	663.00	92.00	96.00		.24	201.00
000149	601.00	89.00	68.00	.35	.28	202.00
000150	490.00	91.00	68.00	.02	.27	203.00
000151	671.00	94.00	66.00		.19	204.00
000152	547.00	95.00	70.00		.25	205.00
000153	516.00	94.00	68.00	.02	.22	206.00
000154	551.00	95.00	72.00		.27	207.00
000155	604.00	93.00	71.00		.27	208.00
000156	582.00	93.00	73.00	.50	.29	209.00
000157	561.00	92.00	73.00	.05	.28	210.00
000158	240.00	85.00	70.00		.30	211.00
000159	434.00	84.00	69.00	1.74	.12	212.00
000160	519.00	89.00	69.00	.68	.15	213.00

PROGRAM LISTING—Continued

000161	609.00	90.00	66.00		.05	214.00
000162	492.00	91.00	68.00		.22	215.00
000163	610.00	93.00	68.00		.25	216.00
000164	623.00	93.00	70.00		.26	217.00
000165	626.00	92.00	70.00		.27	218.00
000166	646.00	92.00	69.00		.25	219.00
000167	635.00	95.00	74.00		.34	220.00
000168	589.00	92.00	74.00		.33	221.00
000169	556.00	95.00	73.00		.27	222.00
000170	461.00	93.00	68.00		.30	223.00
000171	441.00	96.00	67.00		.19	224.00
000172	370.00	94.00	66.00		.23	225.00
000173	356.00	91.00	68.00	.09	.18	226.00
000174	532.00	93.00	68.00		.15	227.00
000175	550.00	89.00	68.00	.25	.24	228.00
000176	480.00	92.00	67.00		.27	229.00
000177	521.00	93.00	68.00		.24	230.00
000178	504.00	92.00	68.00		.25	231.00
000179	566.00	96.00	69.00		.24	232.00
000180	498.00	98.00	70.00		.24	233.00
000181	412.00	99.00	73.00		.29	234.00
000182	439.00	97.00	77.00		.28	235.00
000183	509.00	95.00	68.00		.33	236.00
000184	259.00	96.00	68.00		.21	237.00
000185	402.00	94.00	68.00	.41	.22	238.00
000186	319.00	94.00	69.00	.05	.13	239.00
000187	586.00	93.00	68.00		.16	240.00
000188	584.00	89.00	61.00		.27	241.00
000189	551.00	91.00	62.00		.75	242.00
000190	520.00	92.00	61.00		.22	243.00
000191	460.00	95.00	63.00		.23	244.00
000192	385.00	92.00	69.00		.19	245.00
000193	478.00	95.00	67.00	.03	.19	246.00
000194	435.00	96.00	65.00		.18	247.00
000195	270.00	96.00	67.00		.24	248.00
000196	262.00	90.00	70.00		.13	249.00
000197	514.00	93.00	63.00		.12	250.00
000198	472.00	96.00	73.00		.19	251.00
000199	522.00	98.00	72.00		.22	252.00
000200	495.00	95.00	73.00		.24	253.00
000201	539.00	95.00	68.00		.30	254.00
000202	401.00	91.00	69.00		.21	255.00
000203	485.00	96.00	72.00		.15	256.00
000204	514.00	96.00	61.00		.20	257.00
000205	530.00	97.00	65.00		.30	258.00
000206	503.00	99.00	64.00		.26	259.00
000207	286.00	94.00	67.00		.24	260.00
000208	365.00	96.00	66.00	1.43	.12	261.00
000209	518.00	96.00	69.00	.02	.15	262.00
000210	483.00	94.00	70.00		.23	263.00
000211	478.00	95.00	67.00	.44	.21	264.00
000212	399.00	91.00	66.00		.20	265.00
000213	200.00	90.00	68.00	1.31	.16	266.00
000214	355.00	91.00	68.00	.62	.05	267.00
000215	238.00	90.00	66.00		.13	268.00
000216	162.00	88.00	72.00		.13	269.00
000217	361.00	87.00	67.00		.08	270.00
000218	343.00	88.00	70.00	.45	.17	271.00
000219	365.00	89.00	70.00	.29	.18	272.00
000220	387.00	87.00	69.00	1.22	.12	273.00
000221	544.00	78.00	57.00		.34	274.00
000222	528.00	72.00	41.00		.19	275.00
000223	518.00	78.00	43.00		.15	276.00
000224	456.00	78.00	54.00		.17	277.00
000225	409.00	88.00	65.00	.02	.14	278.00
000226	410.00	87.00	65.00		.17	279.00
000227	355.00	85.00	58.00		.17	280.00
000228	391.00	76.00	64.00		.17	281.00
000229	385.00	78.00	52.00		.09	282.00
000230	395.00	81.00	52.00		.12	283.00
000231	400.00	87.00	51.00		.12	284.00
000232	432.00	86.00	55.00		.17	285.00
000233	409.00	86.00	55.00		.14	286.00
000234	361.00	89.00	58.00		.14	287.00
000235	416.00	90.00	59.00		.14	288.00
000236	339.00	81.00	66.00		.17	289.00
000237	402.00	86.00	53.00		.15	290.00
000238	393.00	90.00	67.00		.15	291.00
000239	351.00	89.00	67.00		.16	292.00
000240	104.00	78.00	50.00	.13	.26	293.00
000241	376.00	70.00	37.00	.03	.05	294.00

```
    271.00     75.00     51.00                     .08    295.00
     43.00     78.00     61.00                     .07    296.00
    346.00     79.00     65.00     1.75            .11    297.00
    141.00     67.00     52.00       .02           .15    298.00
     81.00     60.00     39.00                     .11    299.00
     34.00     57.00     38.00                     .03    300.00
    262.00     65.00     52.00       .55           .07    301.00
     84.00     69.00     48.00                     .02    302.00
     71.00     73.00     52.00                     .03    303.00
     72.00     82.00     54.00                     .08    304.00
    172.00     86.00     66.00                     .00    305.00
*****************************************************************************
PROGRAM SUPPLIED DATA.TABLE OF DECLINATION VALUES FOR SUN.
12345678901234567890123456789012345678901234567890123456789012345678901234567890
-2304               -2242               -2213               -2137
-2054               -2005               -1909               -1808          -1719
               -1610               -1455               -1337               -1215
               -1050               - 923               - 753               - 621
               - 448               - 304               - 139               - 005
                 130                 304            414                 546
            717                 846                1012                1135
           1256                1413      1450                1602
 1709                1811                1909                2002
 2049                2130           2157                2228                2252
                2310                2322                2327                2325
                2317      2310                2252                2228
      2157                2121                2038                1950
      1857           1814                1712                1606
 1455                1341                1223                1102
  936            835                 707                 537                 406
                 234                 101                 032               - 206
      - 253               - 426               - 538               - 729
      - 858               -1025               -1150               -1312
-1411               -1527               -1638               -1745
-1848               -1945               -2036               -2121     -2141
           -2216               -2245               -2306               -2320
           -2326               -2325               -2317
PROGRAM SUPPLIED DATA.TABLE OF WATER STRESS VALUES.
12345678901234567890123456789012345678901234567890123456789012345678901234567890
   .5   .0   .0   .0   .0  2.5   .2   .0   .0   .0  5.0  2.0   .5   .0   .0
  6.8  4.0  2.2  1.0   .5  7.7  5.6  4.0  2.7  2.0  8.7  7.2  6.0  5.0  4.5
  9.0  8.5  7.2  6.5  6.0
*****************************************************************************
USER SUPPLIED DATA.USER MUST FURNISH THE FOLLOWING DATA TO SIMULATE HIS CROP.
12345678901234567890123456789012345678901234567890123456789012345678901234567890
[LATITUDE][SEASON L][SOIL CAP][ EMERGE ][ ROWSP  ][  LEFADD][ PH EFF ][ POPPLT ]
        34       170     1.69        125     101.6      1.35       1.0    41000.
[  POM   ][  EFN   ][INITIALN][ RESIDN ]
      1.0      0.60      20.0      30.0
THE FOLLOWING DATA IS USED BY THE PROGRAM TO VARY THE AMOUNT OF OUTPUT
REQUESTED.JJK-FIRST DAY PRINTED OUT.LAST-EQUAL TO ZERO FOR RUN WITHOUT
MANUAL UPDATING.JB-INCREMENT ADDED TO JJK TO OUTPUT DATA.




[JJK][LAST][ JB ]
   10    0   10
```

EXAMPLE RUNS

The user of SIMCOT II must employ a data file as illustrated in this manual. Two examples are given. In both examples all the data are the same except for the last line of the data file.

Cotton Growth Simulation Run

Data input: SIMCOT II data file, with emphasis on last line as follows:

```
     JJK LAST  JB          ← Variables
 12345678901234567890      ← Column count
      10     0     10      ← The data
```

To execute the program, the user must compile in FORTRAN, map, and execute the absolute element. The data are added to the runstream after the execute command with proper job control language. Given below is the output of SIMCOT II with the above data file as input to the program. Notice that the plant is listed every 10th day; however, this can be changed by the user to suit his needs by changing only the last data card.

The normal output in this case prints the plant out in graphical form. The following symbols indicate plant parts: X, square; *, green boll; #, open boll; 0, abscised site or main-stem node; I, fruiting-branch internode; and =, main-stem internode.

Various parameters are also printed out. All are self-explanatory except "concentrations" and "NPART (1–5)." The concentrations are the concentrations of nitrogen by percent in the leaves, seed, burrs, stems, and roots. NPART (1–5) is the nitrogen accumulation by weight in leaves (1), seed (2), burr (3), stems (4), and roots (5).

INPUT DATA

```
@DATA,L  CLMDATA.,CLMDATA.
DATA006-RLIB67-10  12/05-13:26:31
000001   ,   .020         .20          .20          .00          .10
000002       .020         .20          .20          .00          .05
000003       .020         .20          .20          .00          .20
000004       .020         .20          .20          .00          .30
000005       .020         .20          .20          .00          .40
000006       .020         .20          .20          .00          .48
000007       .020         .20          .20          .00          .56
000008       .020         .20          .20          .00          .64
000009       .020         .20          .20          .00          .72
000010       .020         .20          .20          .00          .80
000011       .030         .30          .30          .00          .92
000012       .030         .30          .30          .00         1.04
000013       .030         .30          .30          .00         1.16
000014       .030         .30          .30          .00         1.28
000015       .030         .30          .30          .00         1.40
000016       .050         .50          .32          .00         1.56
000017       .050         .50          .32          .00         1.72
000018       .050         .50          .32          .00         1.88
000019       .050         .50          .32          .00         2.04
000020       .050         .50          .32          .00         2.20
000021       .080         .80          .48          .00         2.46
000022       .080         .80          .48          .00         2.72
000023       .090         .80          .48          .00         2.98
000024       .080         .80          .48          .00         3.24
000025       .080         .80          .48          .00         3.50
000026       .060         .60          .40          .00         3.70
000027       .060         .60          .40          .00         3.90
000028       .060         .66          .40          .00         4.10
000029       .060         .60          .40          .00         4.30
000030       .060         .60          .40          .00         4.50
000031       .080         .80          .60          .00         4.76
000032       .080         .80          .60          .00         5.02
000033       .080         .80          .60          .00         5.28
000034       .080         .80          .60          .00         5.54
000035       .080         .80          .60          .00         5.80
000036       .080         .80          .60          .00         5.80
000037       .080         .80          .60          .00         5.80
000038       .080         .80          .60          .00         5.80
000039       .080         .80          .60          .00         5.80
000040       .080         .80          .60          .00         5.80
000041       .080         .80          .60          .50         5.80
000042       .040 .040 .050 .060 .070 .100 .225 .225 .225 .225 .225 .225 .225 .225 .225 .225
000043       .225 .225 .225 .225 .225 .225 .225 .225 .225 .225 .215 .200 .195 .190 .175 .160
000044       .150 .130 .120 .110 .100 .095 .080 .075 .070 .060 .050 .040 .035 .030 .027 .020
000045       .15 .010 .009 .007 .005 .004 .002 .001
000046            WEATHER FOR COPIAH COUNTY,MISS. ,1972
```

INPUT DATA—Continued

000047	187					
000048	138.00	80.00	54.00		.06	119.00
000049	468.00	80.00	54.00		.01	120.00
000050	443.00	80.00	54.00		.15	121.00
000051	405.00	86.00	57.00		.20	122.00
000052	208.00	78.00	60.00	1.53	.20	123.00
000053	608.00	79.00	59.00	69	.06	124.00
000054	698.00	77.00	47.00		.25	125.00
000055	589.00	80.00	52.00		.22	126.00
000056	484.00	81.00	50.00		.19	127.00
000057	584.00	76.00	64.00	.10	.18	128.00
000058	584.00	81.00	65.00	.58	.04	129.00
000059	658.00	76.00	60.00		.15	130.00
000060	631.00	74.00	53.00		.22	131.00
000061	446.00	70.00	66.00		.22	132.00
000062	212.00	69.00	64.00	.06	.19	133.00
000063	658.00	81.00	60.00	.80	.09	134.00
000064	663.00	80.00	60.00		.19	135.00
000065	698.00	79.00	56.00	.02	.28	136.00
000066	647.00	86.00	54.00		.28	137.00
000067	547.00	82.00	60.00		.27	138.00
000068	656.00	77.00	55.00		.21	139.00
000069	661.00	78.00	58.00		.26	140.00
000070	645.00	87.00	56.00		.33	141.00
000071	657.00	87.00	56.00		.28	142.00
000072	641.00	91.00	61.00		.29	143.00
000073	648.00	90.00	65.00		.25	144.00
000074	635.00	90.00	73.00		.30	145.00
000075	663.00	88.00	61.00		.27	146.00
000076	596.00	90.00	59.00		.33	147.00
000077	596.00	88.00	62.00		.25	148.00
000078	596.00	89.00	60.00		.29	149.00
000079	395.00	90.00	61.00		.24	150.00
000080	692.00	89.00	59.00		.16	151.00
000081	638.00	81.00	57.00		.32	152.00
000082	706.00	86.00	50.00		.25	153.00
000083	707.00	79.00	46.00		.24	154.00
000084	690.00	90.00	54.00		.28	155.00
000085	685.00	89.00	55.00		.26	156.00
000086	630.00	91.00	54.00		.28	157.00
000087	643.00	91.00	60.00		.28	158.00
000088	515.00	97.00	65.00		.26	159.00
000089	532.00	94.00	65.00		.32	160.00
000090	396.00	93.00	62.00		.23	161.00
000091	493.00	92.00	69.00		.20	162.00
000092	515.00	90.00	65.00		.23	163.00
000093	623.00	90.00	68.00	.04	.22	164.00
000094	410.00	92.00	68.00		.27	165.00
000095	301.00	91.00	69.00	.05	.17	166.00
000096	396.00	92.00	66.00	.13	.11	167.00
000097	352.00	89.00	70.00	.24	.11	168.00
000098	656.00	90.00	70.00	.07	.09	169.00
000099	648.00	91.00	71.00		.23	170.00
000100	652.00	89.00	69.00		.28	171.00
000101	657.00	95.00	65.00		.33	172.00
000102	548.00	91.00	68.00	.34	.36	173.00
000103	326.00	92.00	61.00		.20	174.00
000104	301.00	90.00	62.00	.23	.17	175.00
000105	545.00	92.00	71.00		.10	176.00
000106	241.00	89.00	68.00		.22	177.00
000107	594.00	93.00	72.00	.91	.12	178.00
000108	607.00	94.00	73.00		.26	179.00
000109	554.00	93.00	75.00		.36	180.00
000110	215.00	90.00	70.00		.29	181.00
000111	370.00	94.00	68.00	1.53	.08	182.00
000112	602.00	92.00	68.00	.19	.21	183.00
000113	635.00	93.00	73.00		.26	184.00
000114	260.00	93.00	69.00	.11	.28	185.00
000115	278.00	89.00	67.00	.26	.19	186.00
000116	659.00	77.00	67.00	.15	.11	187.00
000117	669.00	81.00	59.00		.25	188.00
000118	692.00	85.00	57.00		.25	189.00
000119	508.00	86.00	55.00		.23	190.00
000120	611.00	89.00	59.00		.18	191.00
000121	551.00	88.00	65.00		.19	192.00
000122	614.00	91.00	63.00		.22	193.00
000123	630.00	92.00	66.00		.27	194.00
000124	568.00	85.00	63.00	.61	.27	195.00
000125	533.00	89.00	67.00	.58	.27	196.00
000126	461.00	90.00	65.00		.24	197.00
000127	598.00	93.00	70.00		.20	198.00

000128	499.00	88.00	68.00	.83	.28	199.00
000129	627.00	90.00	67.00	.45	.20	200.00
000130	663.00	92.00	96.00		.24	201.00
000131	601.00	89.00	68.00	.35	.28	202.00
000132	490.00	91.00	68.00	.02	.27	203.00
000133	671.00	94.00	66.00		.19	204.00
000134	547.00	95.00	70.00		.25	205.00
000135	516.00	94.00	68.00	.02	.22	206.00
000136	551.00	95.00	72.00		.27	207.00
000137	604.00	93.00	71.00		.27	208.00
000138	582.00	93.00	73.00	.50	.29	209.00
000139	561.00	92.00	73.00	.05	.28	210.00
000140	240.00	85.00	70.00		.30	211.00
000141	434.00	84.00	69.00	1.74	.12	212.00
000142	519.00	89.00	69.00	.60	.15	213.00
000143	609.00	90.00	66.00		.05	214.00
000144	492.00	91.00	68.00		.22	215.00
000145	610.00	93.00	68.00		.25	216.00
000146	623.00	93.00	70.00		.26	217.00
000147	626.00	92.00	70.00		.27	218.00
000148	646.00	92.00	69.00		.25	219.00
000149	635.00	95.00	74.00		.34	220.00
000150	589.00	92.00	74.00		.33	221.00
000151	556.00	95.00	73.00		.27	222.00
000152	461.00	93.00	68.00		.30	223.00
000153	441.00	96.00	67.00		.19	224.00
000154	370.00	94.00	66.00		.23	225.00
000155	356.00	91.00	68.00	.09	.18	226.00
000156	532.00	93.00	68.00		.15	227.00
000157	550.00	89.00	68.00	.25	.24	228.00
000158	480.00	92.00	67.00		.27	229.00
000159	521.00	93.00	68.00		.24	230.00
000160	504.00	92.00	68.00		.25	231.00
000161	566.00	96.00	69.00		.24	232.00
000162	498.00	98.00	70.00		.24	233.00
000163	412.00	99.00	73.00		.29	234.00
000164	439.00	97.00	77.00		.28	235.00
000165	509.00	95.00	68.00		.33	236.00
000166	259.00	96.00	68.00		.21	237.00
000167	402.00	94.00	68.00	.41	.22	238.00
000168	319.00	94.00	69.00	.05	.13	239.00
000169	586.00	93.00	68.00		.16	240.00
000170	584.00	89.00	61.00		.27	241.00
000171	551.00	91.00	62.00		.25	242.00
000172	520.00	92.00	61.00		.22	243.00
000173	460.00	95.00	63.00		.23	244.00
000174	385.00	92.00	69.00		.19	245.00
000175	478.00	95.00	67.00	.03	.19	246.00
000176	435.00	96.00	65.00		.18	247.00
000177	270.00	96.00	67.00		.24	248.00
000178	262.00	90.00	70.00		.13	249.00
000179	514.00	93.00	63.00		.12	250.00
000180	472.00	96.00	73.00		.19	251.00
000181	522.00	98.00	72.00		.22	252.00
000182	495.00	95.00	73.00		.24	253.00
000183	539.00	95.00	68.00		.30	254.00
000184	401.00	91.00	69.00		.21	255.00
000185	485.00	96.00	72.00		.15	256.00
000186	514.00	96.00	61.00		.20	257.00
000187	530.00	97.00	65.00		.30	258.00
000188	503.00	99.00	64.00		.26	259.00
000189	286.00	94.00	67.00		.24	260.00
000190	365.00	96.00	66.00	1.43	.12	261.00
000191	518.00	96.00	69.00	.02	.15	262.00
000192	483.00	94.00	70.00		.23	263.00
000193	478.00	95.00	67.00	.44	.21	264.00
000194	399.00	91.00	66.00		.20	265.00
000195	200.00	90.00	68.00	1.31	.16	266.00
000196	355.00	91.00	68.00	.62	.05	267.00
000197	238.00	90.00	66.00		.13	268.00
000198	162.00	88.00	72.00		.13	269.00
000199	361.00	87.00	67.00		.08	270.00
000200	343.00	88.00	70.00	.45	.17	271.00
000201	365.00	89.00	70.00	.29	.18	272.00
000202	387.00	87.00	69.00	1.22	.12	273.00
000203	544.00	78.00	57.00		.34	274.00
000204	528.00	72.00	41.00		.19	275.00
000205	518.00	78.00	43.00		.15	276.00
000206	458.00	78.00	54.00		.17	277.00
000207	409.00	88.00	65.00	.02	.14	278.00
000208	410.00	87.00	65.00		.17	279.00

000209	355.00	85.00	58.00		.17	280.00
000210	391.00	76.00	64.00		.17	281.00
000211	385.00	78.00	52.00		.09	282.00
000212	395.00	81.00	52.00		.12	283.00
000213	400.00	87.00	51.00		.12	284.00
000214	432.00	86.00	55.00		.17	285.00
000215	409.00	86.00	55.00		.14	286.00
000216	361.00	89.00	58.00		.14	287.00
000217	416.00	90.00	59.00		.14	288.00
000218	339.00	81.00	66.00		.17	289.00
000219	402.00	86.00	53.00		.15	290.00
000220	393.00	90.00	67.00		.15	291.00
000221	351.00	89.00	67.00		.16	292.00
000222	104.00	78.00	50.00	.13	.26	293.00
000223	376.00	70.00	37.00	.03	.05	294.00
000224	271.00	75.00	51.00		.08	295.00
000225	43.00	78.00	61.00		.07	296.00
000226	346.00	79.00	65.00	1.75	.11	297.00
000227	141.00	67.00	52.00	.02	.15	298.00
000228	81.00	60.00	39.00		.11	299.00
000229	34.00	57.00	38.00		.03	300.00
000230	262.00	65.00	52.00	.55	.07	301.00
000231	84.00	69.00	48.00		.02	302.00
000232	71.00	73.00	52.00		.03	303.00
000233	72.00	82.00	54.00		.08	304.00
000234	172.00	86.00	66.00		.00	305.00

000235		-2304				-2242				-2213				-2137			
000236		-2054				-2005				-1909				-1808			-1719
000237					-1610				-1455				-1337				-1215
000238					-1050				- 923				- 753				- 621
000239					- 448				- 3-4				- 139				- 005
000240					130				304			414				546	
000241				717				846				1012				1135	
000242				.1256				1413		1450				1602			
000243		1709				1811				1909				2002			
000244		2049				2130			2157				2228				2252
000245					2310				2322				2327				2325
000246					2317		2310				2252				2228		
000247			2157				2121				2038				1950		
000248			1857			1814				1712				1606			
000249		1455				1341				1223				1102			
000250		936			835				707				537				406
000251					234				101				- 032				- 206
000252			- 253				- 426				- 538				- 729		
000253			- 858				-1025				-1150				-1312		
000254		-1411				-1527				-1638				-1745			
000255		-1848				-1945				-2036				-2121		-2141	
000256				-2216				-2245				-2306				-2320	
000257				-2326				-2325				-2317					
000258		.5	.0	.0	.0	.0	2.5	.2	.0	.0	.0	5.0	2.0	.5	.0	.0	
000259		6.8	4.0	2.2	1.0	.5	7.7	5.6	4.0	2.7	2.0	8.7	7.2	6.0	5.0	4.5	
000260		9.0	8.5	7.2	6.5	6.0											
000261			34		170		1.69		125		101.6		1.35		1.0		41000.
000262			1.0		0.60		20.0		30.0								
000263	NEW	10	0	10													

OUTPUT DATA

```
@XQT   CLMCOT.S
       WEATHER FOR COPIAH COUNTY,MISS.  ,1972
 CONCENTRATIONS    .0420  .0000  .0000   .0200   .0200  NSTRES= 0
 NPART(1-5)     .0264   .0001   .0001   .0103    .0004
== =
DAY  10  CH2O STRESS 0  H2O STRESS    .0   SOLAR RAD  663.  PLANT WT    1.17
SQUARES LOST  0  BOLLS LOST  0  LAI   .08  PHYSIOL. DAYS   6  BLOOMS LOST  0
LEAF WT    .63  MAINSTEM NODES  0 # SQUARES    0 # GREEN BOLLS  0 # SITES    0


== =
 CONCENTRATIONS    .0420  .0000  .0000   .0200   .0200  NSTRES= 0
 NPART(1-5)     .0473   .0001   .0001   .0177    .0008
== =
DAY  20  CH2O STRESS 0  H2O STRESS    .5   SOLAR RAD  635.  PLANT WT    2.05
SQUARES LOST  0  BOLLS LOST  0  LAI   .14  PHYSIOL. DAYS  13  BLOOMS LOST  0
LEAF WT   1.13  MAINSTEM NODES  0 # SQUARES    0 # GREEN BOLLS  0 # SITES    0


== =
 CONCENTRATIONS    .0420  .0000  .0000   .0180   .0200  NSTRES= 0
 NPART(1-5)     .0885   .0001   .0001   .0339    .0042
== =
DAY  30  CH2O STRESS 0  H2O STRESS  1.0   SOLAR RAD  690.  PLANT WT    4.04
SQUARES LOST  0  BOLLS LOST  0  LAI   .26  PHYSIOL. DAYS  20  BLOOMS LOST  0
LEAF WT   2.11  MAINSTEM NODES  0 # SQUARES    0 # GREEN BOLLS  0 # SITES    0


== =
 CONCENTRATIONS    .0420  .0000  .0000   .0176   .0200  NSTRES= 0
 NPART(1-5)     .1597   .0001   .0001   .0690    .0130
== =
DAY  40  CH2O STRESS 0  H2O STRESS  1.0   SOLAR RAD  410.  PLANT WT    7.95
SQUARES LOST  0  BOLLS LOST  0  LAI   .46  PHYSIOL. DAYS  28  BLOOMS LOST  0
LEAF WT   3.80  MAINSTEM NODES  0 # SQUARES    0 # GREEN BOLLS  0 # SITES    0


== =
 CONCENTRATIONS    .0420  .0000  .0000   .0171   .0190  NSTRES= 0
 NPART(1-5)     .2938   .0001   .0001   .1199    .0186
              X   X
              I   I
==0=0=0=0=0=0=0=0=0=
                I
                X
DAY  50  CH2O STRESS 0  H2O STRESS    .0   SOLAR RAD  301.  PLANT WT   14.04
SQUARES LOST  0  BOLLS LOST  0  LAI   .85  PHYSIOL. DAYS  37  BLOOMS LOST  0
LEAF WT   6.99  MAINSTEM NODES  9 # SQUARES    4 # GREEN BOLLS  0 # SITES    4

      X
      I
==0=0=0=

VEGETATIVE BRANCH GROWING FROM NODE  6  OF THE MAIN STEM

 CONCENTRATIONS    .0398  .0000  .0000   .0147   .0117  NSTRES= 0
 NPART(1-5)     .4864   .0001   .0001   .1737    .0122
              X   X
              I   I
              X   X   X   X
              I   I   I   I
==0=0=0=0=0=0=0=0=0=0=0=0=0=0=
                I   I   I
                X   X   X
                I   I
                X   X
DAY  60  CH2O STRESS 0  H2O STRESS    .5   SOLAR RAD  260.  PLANT WT   22.15
SQUARES LOST  0  BOLLS LOST  0  LAI 1.49  PHYSIOL. DAYS  47  BLOOMS LOST  0
LEAF WT 12.23  MAINSTEM NODES 13 # SQUARES   16 # GREEN BOLLS  0 # SITES  16

      X   X   X
      I   I   I
==0=0=0=0=0=0=0=
        I   I
        X   X

VEGETATIVE BRANCH GROWING FROM NODE  6  OF THE MAIN STEM
```

```
 CONCENTRATIONS    .0318  .0000  .0000  .0114  .0097  NSTRES= 1
 NPART(1-5)      .6752    .0001    .0001   .2364   .0119
              X   X
              I   I
              X   X   X   X
              I   I   I   I
              X   X   X   X   X
              I   I   I   I   I
==0=0=0=0=0=0=0=0=0=0=0=0=0=0=0=0=
                I   I   I   I   I
                X   X   X   X   X
                I   I   I
                X   X   X
                I
                X
DAY  70  CH2O STRESS 0  H2O STRESS   .5   SOLAR RAD  568.  PLANT WT  37.72
SQUARES LOST   0  BOLLS LOST   0  LAI 2.58  PHYSIOL. DAYS  55  BLOOMS LOST  0
LEAF WT 21.20  MAINSTEM NODES 16 # SQUARES  29 # GREEN BOLLS  0 # SITES  30

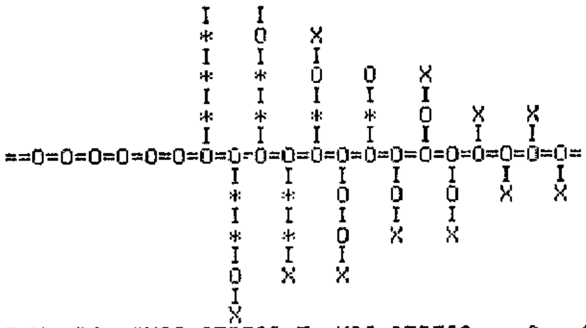
      X
      I
      X   X   X   X
      I   I   I   I
==0=0=0=0=0=0=0=0=0=0=
        I   I   I   I
        X   X   X   X
        I
        0

VEGETATIVE BRANCH GROWING FROM NODE  6  OF THE MAIN STEM

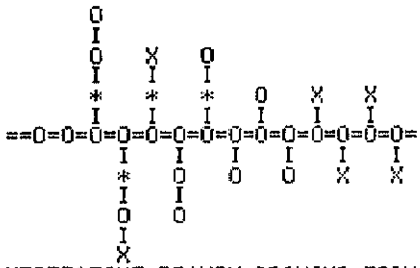
 CONCENTRATIONS    .0262  .0077  .0072  .0082  .0077  NSTRES= 2
 NPART(1-5)      .7525    .0077    .0009   .2792   .0106
              X   X
              I   I
              X   X   X
              I   I   I
              X   X   X   X   X
              I   I   I   I   I
              *   *   X   X   X   X   X
              I   I   I   I   I   I   I
==0=0=0=0=0=0=0=0=0=0=0=0=0=0=0=0=0=0=0=0=
                I   I   I   I   I   I   I
                *   X   X   X   X   X   X
                I   I   I   I   I
                X   X   X   X   X
                I   I   I
                X   X   X
                I
                X
DAY  80  CH2O STRESS 2  H2O STRESS   .5   SOLAR RAD  547.  PLANT WT  54.69
SQUARES LOST   0  BOLLS LOST   0  LAI 3.49  PHYSIOL. DAYS  65  BLOOMS LOST  0
LEAF WT 28.74  MAINSTEM NODES 20 # SQUARES  44 # GREEN BOLLS  4 # SITES  52

      0
      I
      X   X   0
      I   I   I
      *   X   X   X   X   X
      I   I   I   I   I   I
==0=0=0=0=0=0=0=0=0=0=0=0=0=0=
        I   I   I   I   I   I
        X   X   X   X   X   X
        I   I
        0   0
        I
        X
VEGETATIVE BRANCH GROWING FROM NODE  6  OF THE MAIN STEM

CONCENTRATIONS    .0210  .0781  .0061  .0063  .0079  NSTRES= 2
NPART(1-5)      .6925    .0781    .0080   .2792   .0106
              X   X
```

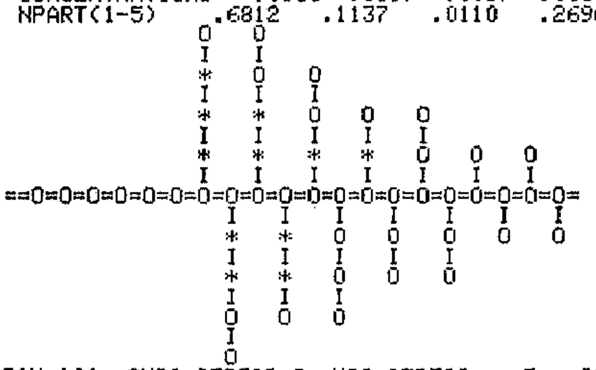


DAY 90 CH2O STRESS 3 H2O STRESS .0 SOLAR RAD 492. PLANT WT 67.50
SQUARES LOST 0 BOLLS LOST 0 LAI 4.00 PHYSIOL. DAYS 75 BLOOMS LOST 0
LEAF WT 32.93 MAINSTEM NODES 20 # SQUARES 19 # GREEN BOLLS 15 # SITES 52

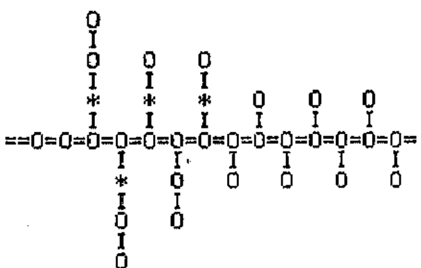


VEGETATIVE BRANCH GROWING FROM NODE 6 OF THE MAIN STEM

CONCENTRATIONS .0186 .1137 .0037 .0051 .0075 NSTRES= 4
NPART(1-5) .6812 .1137 .0110 .2696 .0105



DAY 100 CH2O STRESS 2 H2O STRESS .5 SOLAR RAD 370. PLANT WT 74.70
SQUARES LOST 0 BOLLS LOST 0 LAI 4.44 PHYSIOL. DAYS 84 BLOOMS LOST 0
LEAF WT 36.54 MAINSTEM NODES 20 # SQUARES 0 # GREEN BOLLS 15 # SITES 52



VEGETATIVE BRANCH GROWING FROM NODE 6 OF THE MAIN STEM

OUTPUT DATA—Continued

```
 CONCENTRATIONS    .0175  .1053  .0017  .0043  .0070  NSTRES= 4
 NPART(1-5)     .6851   .1053   .0099   .2694   .0105
              0   0
              I   I
              0   0   0
              I   I   I
              *   0   0   0   0
              I   I   I   I   I
              *   *   0   0   0   0   0
              I   I   I   I   I   I   I
==0=0=0=0=0=0=0=0=0=0=0=0=0=0=0=0=0=0=0=0=0=
                I   I   I   I   I   I   I
                *   *   0   0   0   0   0
                I   I   I   I   I
                0   0   0   0   0
                I   I   I
                0   0   0
                I
                0
DAY 110  CH2O STRESS 1  H2O STRESS  2.2   SOLAR RAD  439.  PLANT WT  83.58
SQUARES LOST  0  BOLLS LOST  0  LAI 4.75  PHYSIOL. DAYS  94  BLOOMS LOST  0
LEAF WT 39.07  MAINSTEM NODES 20 # SQUARES   0 # GREEN BOLLS  7 # SITES  52

      0
      I
      0   0   0
      I   I   I
      *   0   0   0   0   0
      I   I   I   I   I   I
==0=0=0=0=0=0=0=0=0=0=0=0=0=0=
        I   I   I   I   I   I
        *   0   0   0   0   0
        I   I
        0   0
        I
        0
VEGETATIVE BRANCH GROWING FROM NODE  6  OF THE MAIN STEM

 CONCENTRATIONS   .0167  .1195  .0015  .0037  .0067  NSTRES= 4

 NPART(1-5)     .6896   .1195   .0113   .2663   .0108
              0   0
              I   I
              0   0   0
              I   I   I
              *   0   0   0   0
              I   I   I   I   I
              *   *   0   0   0   0   0
              I   I   I   I   I   I   I
==0=0=0=0=0=0=0=0=0=0=0=0=0=0=0=0=0=0=0=0=0=
                I   I   I   I   I   I   I
                *   *   0   0   0   0   0
                I   I   I   I   I
                0   0   0   0   0
                I   I   I
                0   0   0
                I
                0
DAY 120  CH2O STRESS 2  H2O STRESS   .5   SOLAR RAD  385.  PLANT WT  91.90
SQUARES LOST  0  BOLLS LOST  0  LAI 5.01  PHYSIOL. DAYS 103  BLOOMS LOST  0
LEAF WT 41.20  MAINSTEM NODES 20 # SQUARES   0 # GREEN BOLLS  7 # SITES  52

      0
      I
      0   0   0
      I   I   I
      *   0   0   0   0   0
      I   I   I   I   I   I
==0=0=0=0=0=0=0=0=0=0=0=0=0=0=
        I   I   I   I   I   I
        *   0   0   0   0   0
        I   I
        0   0
        I
        0
VEGETATIVE BRANCH GROWING FROM NODE  6  OF THE MAIN STEM
```

```
 CONCENTRATIONS   .0165  .1344  .0016  .0032  .0063  NSTRES= 3
 NPART(1-5)     .6923   .1344   .0133   .2643   .0108
              0   0
              I   I
              0   0   0
              I   I   I
              *   0   0   0   0
              I   I   I   I   I
              #   *   0   0   0   0   0
              I   I   I   I   I   I   I
==0=0=0=0=0=0=0=0=0=0=0=0=0=0=0=0=0=0=0=0=
                I   I   I   I   I   I   I
                #   *   0   0   0   0   0
                I   I   I   I   I
                0   0   0   0   0
                I   I   I
                0   0   0
                I
                0
DAY 130  CH2O STRESS 1  H2O STRESS   .5   SOLAR RAD  401.  PLANT WT  96.72
SQUARES LOST  0  BOLLS LOST  0  LAI 5.12  PHYSIOL. DAYS 112  BLOOMS LOST  0
LEAF WT 42.08  MAINSTEM NODES 20 # SQUARES   0 # GREEN BOLLS  5 # SITES  52

      0
      I
      0   0   0
      I   I   I
      *   0   0   0   0   0
      I   I   I   I   I   I
==0=0=0=0=0=0=0=0=0=0=0=0=0=0=
        I   I   I   I   I   I
        *   0   0   0   0   0
        I   I
        0   0
        I
        0
VEGETATIVE BRANCH GROWING FROM NODE  6  OF THE MAIN STEM

 CONCENTRATIONS   .0177  .1374  .0017  .0028  .0059  NSTRES= 1
 NPART(1-5)     .6948   .1374   .0140   .2730   .0105
              0   0
              I   I
              0   0   0
              I   I   I
              #   0   0   0   0
              I   I   I   I   I
              #   #   0   0   0   0   0
              I   I   I   I   I   I   I
==0=0=0=0=0=0=0=0=0=0=0=0=0=0=0=0=0=0=0=0=
                I   I   I   I   I   I   I
                #   #   0   0   0   0   0
                I   I   I   I   I
                0   0   0   0   0
                I   I   I
                0   0   0
                I
                0
DAY 140  CH2O STRESS 0  H2O STRESS   .0   SOLAR RAD  399.  PLANT WT  98.82
SQUARES LOST  0  BOLLS LOST  0  LAI 4.77  PHYSIOL. DAYS 121  BLOOMS LOST  0
LEAF WT 39.21  MAINSTEM NODES 20 # SQUARES   0 # GREEN BOLLS  0 # SITES  52

      0
      I
      0   0   0
      I   I   I
      #   0   0   0   0   0
      I   I   I   I   I   I
==0=0=0=0=0=0=0=0=0=0=0=0=0=0=
        I   I   I   I   I   I
        #   0   0   0   0   0
        I   I
        0   0
        I
        0
VEGETATIVE BRANCH GROWING FROM NODE  6  OF THE MAIN STEM
```

```
CONCENTRATIONS    .0199  .1374  .0019  .0021   .0052  NSTRES= 0
NPART(1-5)      .7034    .1374    .0155   .2238   .0095
              0   0
              I   I
              0   0   0
              I   I   I
              #   0   0   0   0
              I   I   I   I   I
              #   #   0   0   0   0   0   X
              I   I   I   I   I   I   I   I
==0=0=0=0=0=0=0=0=0=0=0=0=0=0=0=0=0=0=0=0=0=
                I   I   I   I   I   I   I
                #   #   0   0   0   0   0
                I   I   I   I   I
                0   0   0   0   0
                I   I   I
                0   0   0
                I
                0
DAY 150  CH20 STRESS 0  H20 STRESS    .0   SOLAR RAD  528.  PLANT WT  93.29
SQUARES LOST   0  BOLLS LOST   0  LAI 4.29  PHYSIOL. DAYS 130  BLOOMS LOST  0
LEAF WT 35.28  MAINSTEM NODES 21 # SQUARES   1 # GREEN BOLLS  0 # SITES  53
```

```
      0
      I
      0   0   0
      I   I   I
      #   0   0   0   0   0
      I   I   I   I   I   I
==0=0=0=0=0=0=0=0=0=0=0=0=0=0=
        I   I   I   I   I   I
        #   0   0   0   0   0
        I   I
        0   0
        I
        0
VEGETATIVE BRANCH GROWING FROM NODE  6  OF THE MAIN STEM
```

```
CONCENTRATIONS    .0193  .1374  .0020  .0018  .0048  NSTRES= 1
NPART(1-5)      .7204    .1374    .0161   .2092   .0091
              0   0
              I   I
              0   0   0
              I   I   I
              #   0   0   0   0
              I   I   I   I   I
              #   #   0   0   0   0   0   X   X
              I   I   I   I   I   I   I   I   I
==0=0=0=0=0=0=0=0=0=0=0=0=0=0=0=0=0=0=0=0=0=0=0=
                I   I   I   I   I   I   I   I
                #   #   0   0   0   0   0   X
                I   I   I   I   I
                0   0   0   0   0
                I   I   I
                0   0   0
                I
                0
DAY 160  CH20 STRESS 0  H20 STRESS    .0   SOLAR RAD  432.  PLANT WT  94.87
SQUARES LOST   0  BOLLS LOST   0  LAI 4.54  PHYSIOL. DAYS 136  BLOOMS LOST  0
LEAF WT 37.31  MAINSTEM NODES 23 # SQUARES   3 # GREEN BOLLS  0 # SITES  55
```

```
      0
      I
      0   0   0
      I   I   I
      #   0   0   0   0   0
      I   I   I   I   I   I
==0=0=0=0=0=0=0=0=0=0=0=0=0=0=
        I   I   I   I   I   I
        #   0   0   0   0   0
        I   I
        0   0
        I
        0
VEGETATIVE BRANCH GROWING FROM NODE  6  OF THE MAIN STEM
```

OUTPUT DATA—Continued

```
 CONCENTRATIONS    .0196  .1374  .0021  .0014  .0049  NSTRES= 0
 NPART(1-5)      .7409   .1374   .0170   .1743   .0095
              X
              I
              O   O   X
              I   I   I
              O   O   O   X
              I   I   I   I
              #   O   O   O   O   X       X
              I   I   I   I   I   I       I
              #   #   O   O   O   O   O   X   X   X
              I   I   I   I   I   I   I   I   I   I
==O=O=O=O=O=O=O=O=O=O=O=O=O=O=O=O=O=O=O=O=O=O=O=O=O=
                I   I   I   I   I   I   I   I   I
                #   #   O   O   O   O   O   X   X
                I   I   I   I   I   I       I
                O   O   O   O   O   X       X
                I   I   I   I
                O   O   O   X
                I   I
                O   X
DAY 170  CH2O STRESS 0  H2O STRESS   .0   SOLAR RAD  271.  PLANT WT  94.04
SQUARES LOST  0  BOLLS LOST  0  LAI 4.60  PHYSIOL. DAYS 142  BLOOMS LOST  0
LEAF WT 37.80  MAINSTEM NODES 25 # SQUARES  14 # GREEN BOLLS  0 # SITES  66


      O
      I
      O   O   O
      I   I   I
      #   O   O   O   O   O
      I   I   I   I   I   I
==O=O=O=O=O=O=O=O=O=O=O=O=O=O=
        I   I   I   I   I   I
        #   O   O   O   O   O
        I   I
        O   O
        I
        O
VEGETATIVE BRANCH GROWING FROM NODE  6  OF THE MAIN STEM

 YIELD/ACRE 1.679  EMERGENCE DATE 125.  GROWINGDAYS 172  LATITUDE  34.0
# OF GREEN BOLLS  0  # OF OPEN BOLLS  7  SOIL H2O CAPACITY 1.69
H2O RUN OFF  .48  ROW SPACING  101.6  # OF PLANTS/ACRE  41000.


@BRKPT  PRINT$
```

Insect Damage Experiment

The second way in which SIMCOT II can be used is to directly simulate insect damage by removal (changing the fruiting code) of appropriate fruit. Again the same data file is used with the exception of the last card. This program feature was designed to be used on an on-line interactive basis with a demand or time-share terminal but can be used also with card input in the batch mode.

INPUT DATA

SIMCOT II data file, with emphasis on the last card as follows:

```
      JJB LAST  JB          ← Variables
  12345678901234567890      ← Column count
     75     1     0         ← The data
```

In this example, we will simulate bollworm damage in which two squares and three bolls are damaged by bollworms.

Step 1.—Execute program and add data file.

Step 2.—Program stops on the 75th day and asks how many fruit are abscised on day 75.

```
Input:  12345  ← Column count
            1  ← Data
```

Which fruit?

```
Input:  123456789012345  ← Column count
           10     2     4  ← Data
```

The fruit at the tenth main-stem node and first fruiting-branch node is assigned a 4, which is the code for a scar. The reason a 2 is used to indicate the first fruiting-branch node is that the 1 fruiting-branch node is where the fruiting branch is attached to the main stem. The fruit code is as follows: 1 is a square, 2 is a green boll,

3 is a mature boll, and 4 is a scar. On a printout these codes appear as X, *, #, and 0, respectively.

Next the program asks if any fruit on the vegetative branch will be abscised.

```
Input:   12345 ← Column count
             0 ← Data
```

Do you want the plant printed out in graphic form?

```
Input:   12345 ← Column count
             1 ← Data (for "no")
             0 ← Data (for "yes")
```

Are there any more data after today? (Are you manually going to abscise any more fruit?)

```
Input:   12345 ← Column count
             0 ← Data (program proceeds
                   normally)
             1 ← Data (program will ask
                   for more abscission
                   data)
```

What is the next output day (day on which more damage will be inflicted or is of special interest to user)?

```
Input:     JJB ← Variable
         12345 ← Column count
            80 ← Data
```

Step 3.—Abscise square on day 80 on the vegetative branch with the following set of cards:

```
12345678901234567890
  0                  ← No abscission on
                       main stem
  1                  ← Number abscised
                       on vegetative
                       branch
  5    2    4        ← Location on
                       vegetative
                       branch and fruit
                       code
  0                  ← Print plant
  1                  ← More data
 85                  ← Next output day
```

Step 4.—Abscise boll on main stem on day 85 with the following set of cards:

```
12345678901234567890
    1
    9    2    4
    0
    0
    1
   90
```

Step 5.—Abscise boll on main stem on day 90 with the following set of cards:

```
12345678901234567890
    1
    8    2    4
    0
    0
    1
   95
```

Step 6.—Abscise boll on the main stem on day 95 with the following set of cards:

```
12345678901234567890
    1
    7    2    4
    0
    0
    1
  165
```

Step 7.—Print out plants on desired day (in this case on day 105 near the end of the season).

```
12345678901234567890
    0
    0
    0
    0
```

The program with the data file as above and the data outlined in the above example will grow a cotton plant which will lose two squares and three bolls due to insect damage. The program output with the mentioned data now follows.

OUTPUT DATA

```
@XQT   CLMCOT.S
       WEATHER FOR COPIAH COUNTY, MISS. , 1972
  CONCENTRATIONS    .0298   .0006   .0216   .0103   .0078  NSTRES= 1
  NPART(1-5)      .7525   .0006    .0002    .2781    .0106
 HOW MANY FRUIT ON MAIN BRANCH WILL BE ABSCISED ON DAY    75?
    1
 WHICH FRUIT ON MAIN  BRANCH WILL BE ABSCISED ON DAY    75?
   10     2    4
 HOW MANY FRUIT ON VEG. BRANCH WILL BE ABSCISED ON DAY    75 ?
    0
 DO YOU WANT PLANT  PRINTED OUT ON DAY    75?
    0
 IS THERE ANY MORE DATA AFTER DAY    75?
    1
              X
              I
              X   X   X
              I   I   I
              X   X   X   X   X
              I   I   I   I   I
              *   X   X   X   X   X
              I   I   I   I   I   I
==0=0=0=0=0=0=0=0=0=0=0=0=0=0=0=0=0=0=
                I   I   I   I   I   I
                X   X   X   X   X   X
                I   I   I   I
                X   X   X   X
                I   I
                X   X
DAY   75  CH2O STRESS 1  H2O STRESS   .0   SOLAR RAD  627.   PLANT WT   46.32
SQUARES LOST   0  BOLLS LOST   0  LAI 3.07  PHYSIOL. DAYS  60  BLOOMS LOST   0
LEAF WT 25.22  MAINSTEM NODES 18 # SQUARES   38 # GREEN BOLLS   1 # SITES   42

      0
      I
      X   X
      I   I
      X   X   X   X   X
      I   I   I   I   I
==0=0=0=0=0=0=0=0=0=0=0=0=
        I   I   I   I   I
        X   X   X   X   X
        I   I
        0   0
VEGETATIVE BRANCH GROWING FROM NODE  6  OF THE MAIN STEM

THIS IS DAY   75      WHAT IS THE NEXT OUTPUT DAY?
  80
 CONCENTRATIONS    .0262   .0078   .0072   .0082   .0077  NSTRES= 2
 NPART(1-5)      .7524    .0078    .0009    .2792    .0106
HOW MANY FRUIT ON MAIN BRANCH WILL BE ABSCISED ON DAY    80?
   0
HOW MANY FRUIT ON VEG. BRANCH WILL BE ABSCISED ON DAY    80 ?
   1
WHICH FRUIT ON VEG. BRANCH WILL BE ABSCISED ON DAY    80?
   5    2    4
DO YOU WANT PLANT  PRINTED OUT ON DAY    80?
   0
IS THERE ANY MORE DATA AFTER DAY    80?
   1
              X   X
              I   I
              X   X   X
              I   I   I
              X   X   X   X   X
              I   I   I   I   I
              *   *   X   X   X   X   X
              I   I   I   I   I   I   I
==0=0=0=0=0=0=0=0=0=0=0=0=0=0=0=0=0=0=0=0=
                I   I   I   I   I   I   I
                *   0   X   X   X   X   X
                I   I   I   I   I
                X   X   X   X   X
                I   I   I
                X   X   X
                I
                X
DAY  80  CH2O STRESS 2  H2O STRESS   .5   SOLAR RAD  547.   PLANT WT   54.75
SQUARES LOST   0  BOLLS LOST   0  LAI 3.50  PHYSIOL. DAYS  65  BLOOMS LOST   0
LEAF WT 28.76  MAINSTEM NODES 20 # SQUARES   43 # GREEN BOLLS   4 # SITES   52
```

OUTPUT DATA—Continued

```
      O
      I
      X   X   O
      I   I   I
      *   X   X   X   X   X
      I   I   I   I   I   I
==0=0=0=0=0=0=0=0=0=0=0=0=0=0=
        I   I   I   I   I   I
        X   X   X   X   X   X
        I   I
        O   O
        I
        X
VEGETATIVE BRANCH GROWING FROM NODE  6  OF THE MAIN STEM

THIS IS DAY   80      WHAT IS THE NEXT OUTPUT DAY?
  85
 CONCENTRATIONS   .0234  .0304  .0063  .0069  .0077  NSTRES= 2
 NPART(1-5)     .7361   .0304   .0032   .2792   .0106
HOW MANY FRUIT ON MAIN BRANCH WILL BE ABSCISED ON DAY   85?
   1
WHICH FRUIT ON MAIN  BRANCH WILL BE ABSCISED ON DAY   85?
   9    2    4
HOW MANY FRUIT ON VEG. BRANCH WILL BE ABSCISED ON DAY   85 ?
   0
DO YOU WANT PLANT  PRINTED OUT ON DAY   85?
   0
IS THERE ANY MORE DATA AFTER DAY   85?
   1
              X   X
              I   I
              X   X   X
              I   I   I
              *   X   O   X   X
              I   I   I   I   I
              *   *   *   X   X   X   X
              I   I   I   I   I   I   I
==0=0=0=0=0=0=0=0=0=0=0=0=0=0=0=0=0=0=0=0=
                I   I   I   I   I   I   I
                *   O   X   O   X   X   X
                I   I   I   I   I
                *   X   X   X   X
                I   I   I
                O   X   X
                I
                X
DAY  85  CH2O STRESS 2  H2O STRESS   .5   SOLAR RAD  561.   PLANT WT  62.74
SQUARES LOST   2  BOLLS LOST   0  LAI 3.82  PHYSIOL. DAYS  70  BLOOMS LOST   0
LEAF WT 31.44  MAINSTEM NODES 20 # SQUARES  33 # GREEN BOLLS  8 # SITES  52

      O
      I
      O   X   O
      I   I   I
      *   O   X   X   X   X
      I   I   I   I   I   I
==0=0=0=0=0=0=0=0=0=0=0=0=0=0=
        I   I   I   I   I   I
        *   X   O   X   X   X
        I   I
        O   O
        I
        X
VEGETATIVE BRANCH GROWING FROM NODE  6  OF THE MAIN STEM

THIS IS DAY   85      WHAT IS THE NEXT OUTPUT DAY?
  90
 CONCENTRATIONS   .0213  .0659  .0062  .0062  .0078  NSTRES= 2
 NPART(1-5)     .7076   .0659   .0068   .2777   .0104
HOW MANY FRUIT ON MAIN BRANCH WILL BE ABSCISED ON DAY   90?
   1
WHICH FRUIT ON MAIN  BRANCH WILL BE ABSCISED ON DAY   90?
   8    2    4
HOW MANY FRUIT ON VEG. BRANCH WILL BE ABSCISED ON DAY   90 ?
   0
DO YOU WANT PLANT  PRINTED OUT ON DAY   90?
   0
IS THERE ANY MORE DATA AFTER DAY   90?
   1
              X   X
              I   I
              *   O   X
              I   I   I
              *   *   O   O   X
              I   I   I   I   I
              *   O   *   *   O   X   X
```

OUTPUT DATA—Continued

```
              I   I   I   I   I   I   I
==0=0=0=0=0=0=0=0=0=0=0=0=0=0=0=0=0=0=0=0=
                I   I   I   I   I   I   I
                *   0   0   0   0   X   X
                I   I   I   I   I
                *   *   0   X   X
                I   I   I
                0   X   X
                I
                X
DAY  90  CH2O STRESS 2  H2O STRESS   .0   SOLAR RAD  492.  PLANT WT  67.95
SQUARES LOST  0  BOLLS LOST  0  LAI 4.04  PHYSIOL. DAYS  75  BLOOMS LOST  0
LEAF WT 33.25  MAINSTEM NODES 20 # SQUARES  19 # GREEN BOLLS 12 # SITES  52


      0
      I
      0   X   0
      I   I   I
      *   0   *   0   X   X
      I   I   I   I   I   I
==0=0=0=0=0=0=0=0=0=0=0=0=0=0=
        I   I   I   I   I   I
        *   0   0   0   X   X
        I   I
        0   0
        I
        X
VEGETATIVE BRANCH GROWING FROM NODE  6  OF THE MAIN STEM

THIS IS DAY   90      WHAT IS THE NEXT OUTPUT DAY?
  95
 CONCENTRATIONS   .0196  .0896  .0049  .0056  .0076  NSTRES= 4
 NPART(1-5)     .6883   .0896   .0091   .2779   .0104
HOW MANY FRUIT ON MAIN BRANCH WILL BE ABSCISED ON DAY   95?
    1
WHICH FRUIT ON MAIN. BRANCH WILL BE ABSCISED ON DAY   95?
    7     2     4
HOW MANY FRUIT ON VEG. BRANCH WILL BE ABSCISED ON DAY   95 ?
    0
DO YOU WANT PLANT  PRINTED OUT ON DAY   95?
    0
IS THERE ANY MORE DATA AFTER DAY   95?
    1
              0   X
              I   I
              *   0   0
              I   I   I
              *   *   0   0   0
              I   I   I   I   I
              *   0   *   *   0   0   0
              I   I   I   I   I   I   I
==0=0=0=0=0=0=0=0=0=0=0=0=0=0=0=0=0=0=0=0=
                I   I   I   I   I   I   I
                0   0   0   0   0   0   X
                I   I   I   I   I
                *   *   0   0   0
                I   I   I
                0   0   0
                I
                0
DAY  95  CH2O STRESS 1  H2O STRESS  2.0   SOLAR RAD  635.  PLANT WT  72.22
SQUARES LOST  0  BOLLS LOST  0  LAI 4.28  PHYSIOL. DAYS  80  BLOOMS LOST  0
LEAF WT 35.20  MAINSTEM NODES 20 # SQUARES   4 # GREEN BOLLS 11 # SITES  52


      0
      I
      0   0   0
      I   I   I
      *   0   *   0   0   0
      I   I   I   I   I   I
==0=0-0=0=0=0=0=0=0=0=0=0=0=0=
        I   I   I   I   I   I
        *   0   0   0   0   X
        I   I
        0   0
        I
        X
VEGETATIVE BRANCH GROWING FROM NODE  6  OF THE MAIN STEM
```

```
THIS IS DAY   95      WHAT IS THE NEXT OUTPUT DAY?
 165
 CONCENTRATIONS    .0205  .0955  .0015  .0014  .0051  NSTRES= 1
 NPART(1-5)     .7840    .0955    .0090    .1780    .0099
HOW MANY FRUIT ON MAIN BRANCH WILL BE ABSCISED ON DAY  165?
   0
HOW MANY FRUIT ON VEG. BRANCH WILL BE ABSCISED ON DAY  165 ?
   0
DO YOU WANT PLANT  PRINTED OUT ON DAY  165?
   0
IS THERE ANY MORE DATA AFTER DAY  165?
   0
              X
              I
              0   0   X
              I   I   I
              0   0   0   X   X
              I   I   I   I   I
              #   0   0   0   0   X       X
              I   I   I   I   I   I       I
              0   0   #   0   0   0   0   X   X   X
              I   I   I   I   I   I   I   I   I   I
==0=0=0=0=0=0=0=0=0=0=0=0=0=0=0=0=0=0=0=0=0=0=0=0=0=
                I   I   I   I   I   I   I   I   I
                0   0   0   0   0   0   0   X   X
                I   I   I   I   I   I
                #   0   0   0   0   X
                I   I   I   I
                0   0   0   X
                I   I
                0   X

DAY 165  CH2O STRESS 0  H2O STRESS   .0   SOLAR RAD  402.  PLANT WT  88.47
SQUARES LOST  0  BOLLS LOST  0  LAI 4.66  PHYSIOL. DAYS 139  BLOOMS LOST  0
LEAF WT 38.29  MAINSTEM NODES 25 # SQUARES  14 # GREEN BOLLS  0 # SITES  66

      0
      I
      0   0   0
      I   I   I
      #   0   0   0   0   0
      I   I   I   I   I   I
==0=0=0=0=0=0=0=0=0=0=0=0=0=0=
        I   I   I   I   I   I
        #   0   0   0   0   0
        I   I
        0   0
        I
        0
VEGETATIVE BRANCH GROWING FROM NODE  6  OF THE MAIN STEM

 YIELD/ACRE 1.272  EMERGENCE DATE 125.  GROWINGDAYS 172  LATITUDE  34.0
# OF GREEN BOLLS  0  # OF OPEN BOLLS  5  SOIL H2O CAPACITY 1.69
H2O RUN OFF   .48  ROW SPACING  101.6  # OF PLANTS/ACRE  41000.
```

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PART 5.—HARVSIM: A SIMULATION OF COTTON HARVESTING AND GINNING

By James W. Jones,[1] Rex F. Colwick,[2] D. F. Wanjura,[3] and Elmer B. Hudspeth[4]

DESCRIPTION

HARVSIM simulates harvesting, transporting, storing, and ginning of cotton from a farm in a gin community. See figure 5–1. The focus is on a particular farm where field sizes, cotton maturity rates for each field, and yield of each field are descriptions of the crop. The harvesting and hauling system is specified by the number, capacity, and speed of harvesters and the number and capacity of trailers available to the farmer. The rest of the cotton input to the gin from other farms is simulated by random lumped harvesting rates derived from past gin records. The ginning rate is specified, and an option exists for altering the gin schedule. Breakdowns of harvesters and the gin are simulated, and idle harvester time due to trailer shortages is considered. A trailer hauler takes one or two trailers to and from the gin.

The operator specifies the date when harvesting is to start by selecting the percentage of the crop open when harvesting is to start. Rainfall is an input to the model, and depending on the amount of rainfall, harvesting is stopped for 0, 1, 2, 3, or 4 days with certain probabilities. Daily trailer arrivals from the entire gin community are calculated and include arrivals from the farm under study. The system status is updated every 0.1 hour. Harvesting is simulated for each harvester, each harvester having been assigned to a field, and a trailer is assigned to each harvester for filling. Harvester breakdown and repair times are simulated. Harvesting continues until all fields are harvested once unless a trailer shortage prevents the harvester from unloading. Farm management determines whether to harvest each field twice and specifies a value (in bales per acre remaining in the field) below which the field will not be harvested a second time.

A hauler transports one or two full trailers to the gin and returns trailers to the farm. When trailers from the farm arrive at the gin, they are placed in a first-come, first-served queue. A daily operating schedule for the gin is selected, based on gin backlog. Breakdowns and repair times for gin equipment are simulated. An economic analysis calculates costs for harvesting, transporting, and ginning.

HARVSIM was validated with 1-year data from the Texas High Plains. The simulated and observed harvesting rates and trailer requirements compared well for the two farms that were monitored.

LIMITATIONS

HARVSIM was intended for comparing current methods of handling seed cotton with alternate methods that include seed-cotton storage prior to ginning. The model depicts the current trailer method and focuses on an individual farm, but with estimates of harvested cotton from the rest of the gin community. A second model was developed (HARSTOR) to simulate storage of seed cotton on all farms in a gin community and will be reported later.

HARVSIM is limited to studying individual farm harvesting decisions and the effects of these decisions on costs, harvester idle time,

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labor requirements, etc. Farm decisions throughout a gin community can also be studied, but the lumped gin input will have to be altered to reflect that change. For example, one could study the effect of a constant number of trailers owned by the gin and used on a first-come, first-served basis by changing the community harvesting rates to reflect that process.

The economic analysis for the gin is based totally on High Plains gin data developed at Texas Technological University, Lubbock.[5] A more detailed economic analysis of gin costs is needed to make the model general. The harvesting-hauling economic analysis is based on American Society of Agricultural Engineers cost figures.

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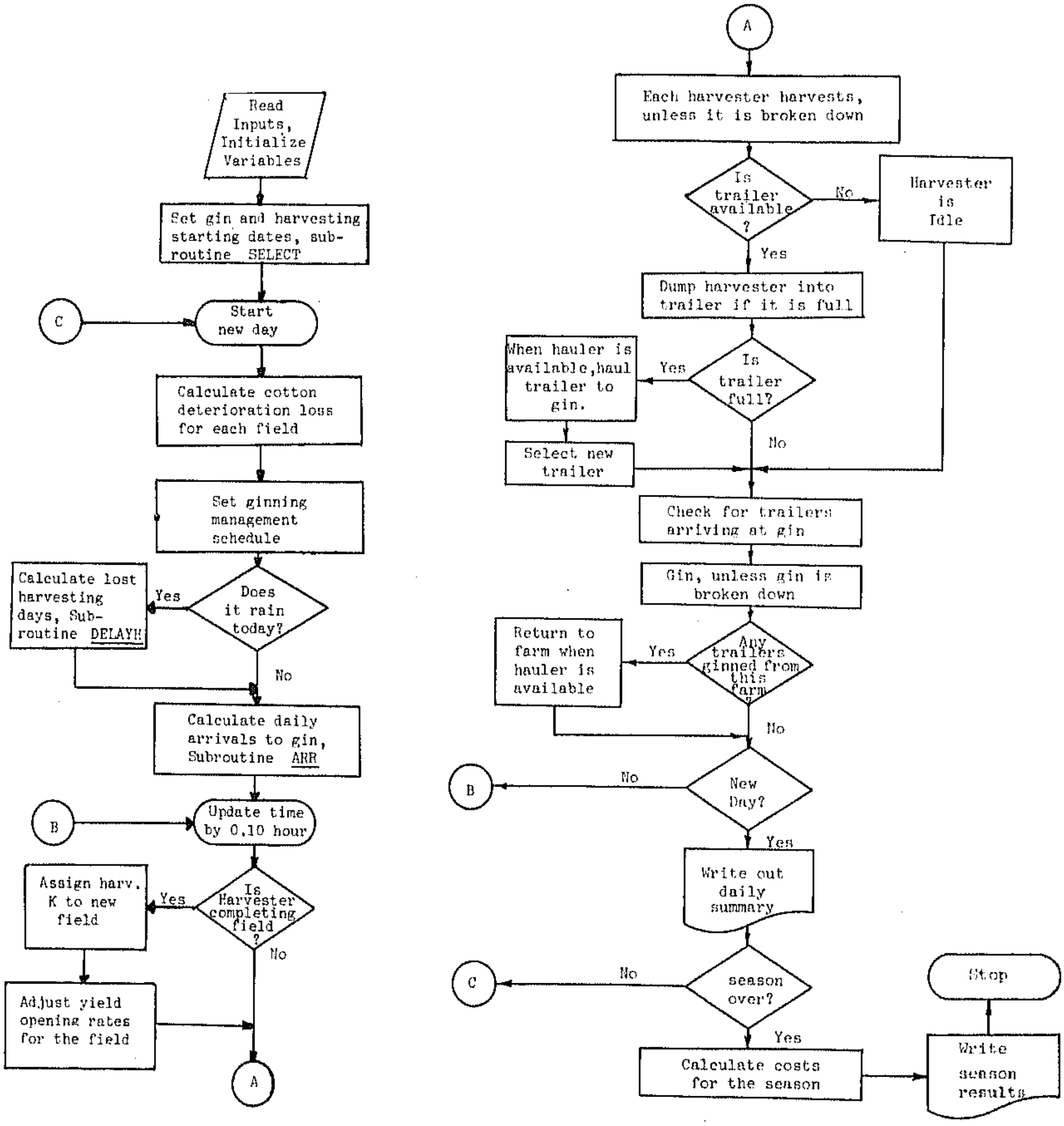

FIGURE 5-1.—Simplified flow chart for HARVSIM.

DEFINITION OF TERMS

ACDELT	Acres harvested in one time increment.
ACS(K)	Number of acres in field K (K=1–50).
ACST	Total acres on farm.
AIDT	Amount harvested in one time increment.
AR	Bales arriving at gin today from rest of gin community.
ARPH	Arrival rate in bales per hour.
BGND	Total bales ginned.
BH	Probability of harvester breaking down within a time increment.
BKLG	Bales in gin yard not yet ginned.
BLLS	Total bales harvested from this farm.
CCOT	Cost per pound of lint.
CDEP	Depreciation cost, harvester.
CFLBR	Cost of farm labor for year.
CGIN	Total gin cost per year.
CGLBR	Cost of gin labor for unloading system.
CHARN	Total harvesting cost per year.
CHAUL	Total yearly cost for hauling.
CHL	Cost per mile to operate pickup hauler.
CINS	Insurance cost, harvester.
CINT	Interest cost, harvester.
CLBR	Cost per hour for labor.
CLOSF	Percentage of cotton loss 30 days after boll opening.
CLUB	Lubrication cost per year, harvester.
COTT(K)	Amount of cotton remaining in field K.
COTTT	Total seed cotton on farm.
CTAX	Cost of taxes per year (harvester).
CTLS	Cost per trailer per year.
CTR	Total trailer cost, all trailers.
DGIN	Daily gin volume.
DLAY	Number of days harvesting delayed due to rain.
EFF	Efficiency of harvester.
ENQ	Time when hauler is to arrive at gin.
ENT(JK)	Time trailer JK arrives at gin.
FLDFLG(K)	Harvest status for field K (0=not yet harvested; 1=harvested once; 2=harvested twice).
FOX	Percentage of gin volume arriving today, excluding farm in question.
GAMT	Amount ginned during one time increment.
GCPB	Ginning cost per bale, from study cited in footnote 5.
GDT	Repair time for gin.
GINAR	Midseason daily average gin arrival rate if user wants to specify this.
GOP	Time gin starts running after breakdown.
GRTE	Ginning capacity in bales per hour.
GTO	Gin turnout in percent.
HAMT(J)	Pounds of seed cotton in harvester J.
HARC	Purchase price for harvester.
HARTOL	Tolerance for simulating when the harvester dumps the cotton.
HPH	Hours of harvester operation.
IARFLG	Flag for reading in gin arrival rate parameters or simulating (1=read in, 0=simulate).
ICNT	Counts empty trailers in gin yard belonging to this farm.
IDAL	Days from first open cotton.
IDAY	Day number.
IDL(J)	Total idle time due to trailer shortages for harvester J.
IDT	Time counter during day; each increment is 10 minutes.
IFIELD(K)	Harvester number assigned to field K for harvesting.
IFK	Field DO loop counter.
IFLAG(K)	Trailer status flag: 0=waiting to be filled, 1=being loaded, 2=trailer full, 3=in transit to gin, 4=in gin queue, 5=empty at gin, and 6=trailer on way home.
IGFLG	Gin operating flag.
IGSTRT	Flag for reading (IGSTRT=0) or calculating gin and harvest starting dates (IGSTRT=1).
IGT	Number of time increments the gin operates today, at 10 minutes each.
IHARV(J)	Field number assigned to harvester J for harvesting (a pointer).
IHEND	Time of day to stop harvest.
IHLR	Trailer hauler status: 0=on farm, 1=on way to gin, 2=at the gin, 3=on way to farm.
IHSTRT	Time of day for starting harvest (0=6:00 a.m., 10=7:00, etc; daily time increment=0.1 hour).
ILAST	Number of days required for season to "tail off" after arrivals start slowing down at end of season.
IMID	Average number of days for arrivals occurring at the midseason rate, total gin community.
INOTIM	Number of current harvest, 1 or 2.
IQN(JL)	Time that trailer JL is ginned.
IQUIT	Number of harvesters completed harvesting for the year.
IRAIN	Flag for reading rain (IRAIN=1) or simulating it (IRAIN=0). (It must be equal to 1 in this program.)
IRDA	Julian days of rainfall input.
IRTRN	Time that hauler returns to farm.
ISH(JFK)	Time when harvester starts harvesting after a breakdown (current time plus repair time).
ISTART	Day when harvest is resumed after a rain.
ISTRT	Number of days required for gin arrival rate to reach midseason average.
ITACS	Total acres harvested to date.
JFK	Harvester counter.
JFLAG(J)	Harvester status flag: 0=harvester can dump load into harvester and 1=idle harvester.
KTT,IZ	Number of trailers hauler pulls to gin this time, 1 or 2.
LBH	Pounds of seed cotton per bale.
LIFE	Years for depreciating harvester.

MASTRT	First day of open cotton.
MATRTE (K,I)	Percent of cotton open on day I (I=1–50 days after MASTRT for field K (K=1–50).
NA	Number of days gin arrivals is increasing in trend (=ISTRT if read in).
NB	Number of days before gin receipts show decline at end of season (=IMID if read in).
NC	End of gin season (=ILAST if read in).
NDAY	Number of days charged for ginning.
NFLD	Number of fields on the farm, ranked in order of earliness.
NGLBR	Number of gin laborers used for unloading system.
NHAUL	Number of trips (total) made to gin.
NHVS	Number of harvesters on the farm.
NOFTIM	Number of harvests per field, 1 or 2.
NRAIN	Number of days of rainfall to read.
NSGN (K)	Harvester number assigned to trailer K.
NTH	Total number of days harvesting, including rain days.
NTLS	Number of trailers on the farm.
NYR	Number of years to be simulated.
PSTART	Percentage of bolls open for starting harvest.
QO	Theoretical acres per hour.
R	Rainfall on day in question.
RFIN (IRDA)	Rainfall amounts on day IRDA.
RL (K)	Row length in field K (K=1–50).
RO	Probability of gin breakdown during one time increment.
RT (I)	Time trailer I is scheduled to return to farm.
SAVCOT	Temporary variable to store amount of cotton remaining in each field.
SGRT	Variation about ginning rate.
SMALY	Lowest yield such that if a field has less than SMALY bales per acre in it, then it will not be harvested.
SV	Salvage value of harvester.
SYA	Standard deviation of YAK.
TACRE	Actual time required per acre.
TACS (K)	Total acres in field K harvested during current harvest.
TAMI (K)	Amount of seed cotton in trailer K.
TCAP	Trailer capacity.
TCN	Total cotton harvested to date.
TCPB	Total cost per bale harvested on farm.
TENQ	Total time elapsed when hauler arrives at gin.
TIDT	Total time increments.
TNBLS	Total arrivals at gin in bales.
TQO	Theoretical time per acre.
TRD	Time to drive to or from gin.
TTRIP	Time required for a harvester round trip in field.
VEL	Average harvesting velocity in miles per hour.
VOL	Gin community volume in bales.
XMI	Miles to the gin.
XO	Amount held by each harvester in pounds.
X, RNX	Random numbers.
YA (K)	Yield per acre in field K (K=1–50).
YAK	(Dummy) yield that has opened.
YLO	Loss of cotton from a field.
YLOS	Total lost cotton, accumulated.

INPUT/OUTPUT

Input

Card 1: Col.
1–5	NYR (Integer)	
6–10	NHVS (Integer)	
11–15	NTLS (Integer)	
16–20	NFLD (Integer)	
21–25	NOFTIM (Integer)	
26–35	XMI (F10.2)	
36–45	GTO (F10.2)	
46–55	CLBR (F10.2)	
56–65	GRTE (F10.2)	
66–75	SMALY (F10.2)	

If NFLD is 6:

Cards 2 through 7; 1 card for each field.

Col.		
1–10	ACS (K)	(F10.2)
11–20	YA (K)	(F10.2)
21–30	RL (K)	(F10.2)

Card 8: Col. 1–5 MASTRT (Integer)
6–15 PSTART (F10.2)

Card 9 through 24: MATRE (K,I) arranged in F4.2 format starting with field 1; 50 values are read in for maturity values for each field K.

Card 25: Col.
1–10	CTLS	(F10.2)
11–20	CHL	(F10.2)
21–30	VOL	(F10.2)
31–40	HARC	(F10.2)
41–50	SV	(F10.2)
51–55	LIFE	(Integer)

Card 26: Col.
1–10	TCAP	(F10.2)
11–20	CCOT	(F10.2)
21–30	VEL	(F10.2)
31–40	GINAR	(F10.2)
41–45	ISTRT	(F5.0)
51–55	ILAST	(F5.0)
56–60	IARFLG	(Integer)

Card 27: Col.
1–5	IRAIN	(Integer)
6–10	NRAIN	(Integer)

Card 28: As many cards as needed, only if rain is read in.

Col. 1–5 IRDA (day of rain, Integer)
6–10 RFIN (IRDA) (F5.2)
Repeat as needed on same card

and on following cards if needed.

Card 29:	Col.	1–10	CLOSF	(F10.3)
		11–15	IHSTRT	(Integer)
		16–20	IHEND	(Integer)
		21–30	HARCAP	(F10.3)
Card 30:	Col.	1–5	IGSTRT	(Integer)
		6–10	NSG	(Integer)
		11–15	NGLBR	(Integer)

Output

1. Number of harvesters, trailers, and distance to the gin are printed out.
2. For each field, the number of acres, yield, and row length are printed.
3. The total cotton to harvest, gin starting date, and harvesting starting date.
4. Daily gin summary including the number of arrivals, bales ginned, backlog, and hours of operation.
5. Breakdowns are printed when they occur (gin and harvester).
6. Every time a harvester or trailer changes status, the change is printed out, for example, when a harvester is filled and dumped into a trailer, when a trailer returns to the farm, and when a trailer is ginned are outputs.
7. A daily summary is printed for harvesting and ginning.
8. At the end of the season, the trailer utilization is printed for each trailer. The number of bales harvested, hours of harvester operation, and costs per bale are printed out.

PROGRAM SETUP AND EXECUTION

HARVSIM is programed in FORTRAN for a UNIVAC 1106 or IBM 370 computer. The card reader input unit is 1 and the line printer output unit is 3.

The card deck is arranged in the following sequence for a UNIVAC run:

A. Control cards
   1. @RUN
   2. @ASG
   3. @FOR

B. Main program deck

C. @FOR card (in front of each subroutine)

— Subroutine (s) —

D. @MAP card

IN card

E. @XQT card

—data—

F. @FIN card

The @RUN card specifies account number, name of run, and the project qualifier. The @ASG card assigns space on disk for storing the program for future use. The @FOR cards cause the main program and subroutines to be compiled with the FORTRAN compiler. The @MAP card creates an absolute element in machine language with all subroutines linked together for the run and for future runs if desirable. The @XQT card causes program execution, and @FIN signals the end of the program.

PROGRAM LISTING

```
C       HARVESTING-HANDLING SIMULATION
        REAL IDL(4),HAMT(4),ENT(30),TAMT(30),RT(30),TE(30),TT(30),RFIN(400
       1),ISTRT,IMID,ILAST
        DIMENSION     X(1)
        INTEGER TIDT
        INTEGER FLDFLG(50),IFIELD(50),IHARV(4)
        INTEGER IFLAG(30),ION(30),ISH(4),NSGN(30),JFLAG(4)
        DIMENSION ACS(50),YA(50),RL(50),COTT(50),TACS(50)
        REAL*4 MATRTE(50,50)
        DATA IDL/4*0./,HAMT/4*0./,ENT/30*0./,TAMT/30*0./,RT/30*0./,TE/30*0
       1./,TT/30*0./
        DATA TIDT/0/,JFLAG/4*0/,IFLAG/30*0/,ION/30*0/,RFIN/400*0.0/,
       1ISH    /4*0/,NSGN     /30*0/,FLDFLG/50*0/
        DATA IHARV/4*0/,IFIELD/50*0/,TACS/50*0.0/,COTT/50*0.0/
C       1971 RAINFALL DATA FOR LUBBOCK, TEXAS
        NSHIFT=2
C       THE FOLLOWING STATEMENTS INITIALIZE VARIABLES
        IN=1
        DATA NHAUL/0/,IHLR/0/,IRTRN/0/
        DATA IBD/0/,BGND/0./,TNBLS/0./,BKLG/0./,GOP/0./,ISTART/0/
C       READ IN VARIABLES FOR THIS SIMULATION
C       NYR=NUMBER OF YEARS TO BE SIMULATED
C       NTLS=NUMBER OF TRAILERS HE OWNS
C       NHVS=NUMBER OF HARVESTERS FARMER OWNS
C          ACS(K) - NO. ACRES IN FIELD K.
C          YA(K). - AVERAGE YIELD PER ACRE IN FIELD K
C                (ADJUSTED WHEN HARVEST OCCURS)
C          RL(K) - ROW LENGTH IN FIELD K.
C          COTT(K) - AMOUNT OF COTTON REMAINING EACH FIELD
C       XMI=AVERAGE DIST. TO GIN
C       GTO=GIN TURNOUT
C       CLBR=LABOR COST PER HOUR
C       GRTE=GIN CAPACITY PER HOUR, RATED
C       CLOT=COST PER LB. OF LINT LOST
C          NOFTIM - NO. OF TIMES TO HARVEST, 1 OR 2.
C          INOTIM - CURRENT HARVEST, 1 = FIRST, 2 = SECOND TIME
C          NFLD - NO. OF FIELDS ON THE FARM.
C          MASTRT - STARTING DAY NO. FOR READ IN MATURITY CURVES.
C          MATRTE(I,K) - MATURITY RATE, PERCENT OF FINAL YIELD  OPEN
C                ON DAY K, FOR FIELD I.
C          SMALY - SMALLEST YIELD THAT WE WILL HARVEST, >=0.0
C          IRAIN - FLAG FOR READING IN RAIN OR SIMULATING IT.
C             0 = SIMULATED      1 = READ IN
C          NRAIN - NO. OF RAINFALL DAYS TO READ IN.
C          IHARV(J) - FIELD NO. ASSIGNED TO HARVESTER J.
C          FLDFLG(K) - HARVEST STATUS FOR FIELD
C                0 = NOT YET HARVESTED   1 = HARVESTED 1 TIME
C                2 = HARVESTED 2 TIMES
C          TACS(K) - TOTAL ACRES COMPLETED HARVESTING, FIELD K,
C                FOR THIS PARTICULAR HARVEST.
C          IQUIT - NO. OF HARVESTERS RETIRED FOR THE SEASON
C
C
C
        READ(1,1) NYR,NHVS,NTLS,NFLD,NOFTIM,XMI,GTO,CLBR,GRTE,SMALY
    1   FORMAT(5I5,5F10.2)
        READ(1,1111)(ACS(K),YA(K),RL(K),K=1,NFLD)
 1111   FORMAT(3F10.2)
        READ(1,1140) MASTRT,PSTART
 1140   FORMAT(I5,F10.2)
        IN=1
        X(1)=0.62412
        READ(1,1112)((MATRTE(I,K),K=1,50),I=1,NFLD)
 1112   FORMAT(20F4.2)
        READ(1,501) CTLS,CHL,VOL,HARC,SV,LIFE
        READ(1,927) TCAP,CCOT,VEL,GINAR,ISTRT,IMID,ILAST,IARFLG
        READ(1,760) IRAIN,NRAIN
  760   FORMAT(2I5)
        IF(IRAIN.EQ.1) READ(1,761)(IRDA,RFIN(IRDA),I=1,NRAIN)
  761   FORMAT(8(I5,F5.2))
        IQUIT=0
  501   FORMAT(5F10.2,I5,F10.2)
  927   FORMAT(4F10.2,3F5.0,I5)
```

PROGRAM LISTING—Continued

```
      INOTIM=1
      IX=78347
      TCAP=(TCAP*479./GTO)*100.
C     FOLLOWING STMT. ACCOUNTS FOR EXTRACTOR COTTON
      GRTE=GRTE+GRTE*(5.8333*(GTO-21.3)/100.)
C
C
      YLO=0.0
      YLOS=0.
      WRITE(3,610)
  610 FORMAT('1',10X,'HARVEST-GIN  FOR N.C. STATE EXAMPLE')
      WRITE(3,614)
  614 FORMAT('0',4X,'                    NO.HARV.  NO.TRAILERS   TRAILER CAP.
     1  DIST.TO GIN')
      WRITE(3,611)            NHVS,NTLS,TCAP,XMI
  611 FORMAT('0',21X,I3,8X,I3,9X,F7.1,8X,F5.1,/)
      WRITE(3,1109)
 1109 FORMAT('0',2X,'FIELD',15X,'ACRES',15X,'YIELD',10X,'ROW LENGTH')
      WRITE(3,1113)(IFK,ACS(IFK),YA(IFK),RL(IFK),IFK=1,NFLD)
 1113 FORMAT(' ',I5,7X,F15.2,5X,F15.2,3X,F15.2)
C     START A NEW YEAR
      IYR=0
      READ(1,759) CLOSF,IHSTRT,IHEND,HARCAP
  759 FORMAT(F10.3,2I5,F10.3)
C         CLOSF = COTTON LOSS FACTOR
C         IHSTRT = BEGIN HARVEST (0 IS 6:00 A.M.)
C         IHEND = STOP HARVEST.
 1000 IYR=IYR+1
C     TCN IS TOTAL COTTON HARV THIS YEAR
C     TIACS IS TOTAL ACRES HARV THIS YEAR
      TCN=0.
C     SELECT COMPUTES THE GIN STARTING DATE, AND THE HARVEST STARTING DAY
      READ(1,751) IGSTRT,NSG,NSH,NGLBR
  751 FORMAT(4I5)
      ACST=0
      COTTT=0
      TIACS=0
      DO 1114 IFK=1,NFLD
      COTT(IFK)=(ACS(IFK)*YA(IFK)*100.0/GTO)*479.0
      ACST=ACST+ACS(IFK)
 1114 COTTT=COTTT+COTT(IFK)
      IF(IGSTRT.EQ.1) GO TO 750
      CALL SELECT(NSG,NSH,X,IX,PSTART,MASTRT,MATRTE)
 750  WRITE(3,60)NSG,NSH,COTTT
   60 FORMAT(' ','GIN STARTING DAY IS',I4,//,'HHARV. STARTING DAY IS',
     1I4,//,'TTOTAL COTTON TO HARVEST IS',F10.1,'POUNDS',//)
C
C
C
C         ASSIGNS HARVESTERS TO FIELDS INITIALLY
C         IFIELD(K) - HARVESTER NO. ASSIGNED TO FIELD K.
      DO 1117 J=1,NHVS
      IFIELD(J)=J
 1117 IHARV(J)=J
C
C     IDAY=DAY NO.
      DO 999 IDAY=NSG,388
      IDAL=IDAY-MASTRT+1
      IF(IDAL.GT.50) IDAL=50
C
C         IDAL - NO. OF DAYS SINCE SEED COTTON STARTED
C           OPENING, MAX. OF 50.
C
C         COTTON DETERIORATION FACTOR, CLOSF
C
      IF(IDAY.LT.MASTRT+30) GO TO 1115
      IDAQ=IDAY-(MASTRT+30)+1
      IF(IDAQ.GT.50)IDAQ=50
      DO 1116 IFK=1,NFLD
      SAVCOT=COTT(IFK)
      COTT(IFK)=COTT(IFK)*(1.0-(CLOSF*MATRTE(IFK,IDAQ))*((ACS(IFK)-TACS(
     1IFK))/ACS(IFK)))
      YLO=SAVCOT-COTT(IFK)
      IF(YLO.LT.0.0) YLO=0.0
      YA(IFK)=YA(IFK)*(1.0-CLOSF*MATRTE(IFK,IDAQ))
 1116 YLOS=YLOS+YLO
      WRITE(3,10778) YLOS
10778 FORMAT(' ','YLOS= ',F10.2)
 1115 CONTINUE
```

```
      IDT=0
C
C     DELAYH IS FOR SIMULATING RAIN AND DELAYSIN HARV. DUE TO RAIN
C     ISTART IS STARTING DAY FOR HARVEST AFTER RAINFALL
      CALL DELAYH(X,NN,R,IDAY,ISTART,IRAIN,RFIN)
C
C     THIS SUBROUTINE CALCULATES ARRIVALS FOR THE DAY AND DETERMINES
C     WHETHER GIN IS RUNNING
C     AR=BALES ARRIVED AT GIN TODAY
C     IGFLG=0 MEANS GIN IS OPERATING; IGFLG=1 MEANS RAINED OUT
C    IF ISTART .GT. IDAY,IAR.GT. 0 AND NO. GIN ARRIVALS FOR DAY
      NDAY=IDAY-NSG-(IDAY-NSG)/7
      IAR=ISTART-IDAY
      CALL ARR(R,X,NN,AR,NDAY,IGFLG,VOL,IAR,GINAR,ISTRT,IMID,ILAST,IARFL
     1G)
      IF(IDAY/7*7-IDAY.EQ.0)AR=0
C     IF THERE IS A DELAY IN HARV. DUE TO RAIN, GO TO GINNING
C
C        ***********************************************************
C        FOLLOWING IS GIN MANAGEMENT SCHEDULE BASED ON BACKLOG.
C
      IGT=110
      IF(BKLG.GT.100.AND.NSHIFT.EQ.2)IGT=230
      IF(BKLG.GT.100.) GRTE=16.8
      IF(IDAY.GE.NSG+56) IGT=110
      IF(IDAY.GE.NSG+56) GRTE=16.8
C
C        ***********************************************************
C
      DGIN=0.
C     IDT IS TIME COUNTER DURING DAY
   20 IDT=IDT+1
C     TIDT=TOTAL NO. OF TIME INCREMENTS
      TIDT=TIDT+1
      IF(IDAY.LT.NSH.OR.IDAY.LE.ISTART) GO TO 6
      IF(IDAY/7*7-IDAY.EQ.0) GO TO 6
C        HARVEST BETWEEN IHSTRT AND IHEND, 0=6:00 A.M.
      IF(IDT.LE.IHSTRT.OR.IDT.GT.IHEND) GO TO 6
C
      IF(IQUIT.EQ.NHVS) GO TO 1123
 1124 CONTINUE
C
C        CHECK FOR HARVESTERS COMPLETING A FIELD
C
      DO 1119 JFK=1,NHVS
      IU=IHARV(JFK)
      IF(IHARV(JFK).EQ.0) GO TO 1126
      IF(TACS(IU        ).LT.ACS(IU        )) GO TO 1119
      IFIELD(IU        )=0
      FLDFLG(IU        )=1
      IF(INOTIM.EQ.2) FLDFLG(IU        )=2
      TACS(IU        )=0.0
      WRITE(3,1130) IHARV(JFK),IDAY,FLDFLG(IU         ),COTT(IU
      YA(IU        )=COTT(IU         )/(ACS(IU         ))*GTO/47900.0
      WRITE(3,7111) YA(IU        )
 7111 FORMAT(' ','YA  ',F10.5)
      IHARV(JFK)=0
 1126 CONTINUE
C
C        SELECT NEW FIELD FOR HARVESTER JFK
C
      DO 1120 IFK=1,NFLD
      IF(IFIELD(IFK).GT.0) GO TO 1120
      IF(YA(IFK).LT.SMALY) GO TO 1120
      IF(MATRTE(IFK,IDAL).LT.0.99.AND.INOTIM.EQ.2) GO TO 1120
      IF(FLDFLG(IFK).EQ.INOTIM-1) GO TO 1121
 1120 CONTINUE
      IF(INOTIM.EQ.2) IHARV(JFK)=0
      IF(INOTIM.EQ.2) GO TO 1119
      IF(NOFTIM.EQ.1) IHARV(JFK)=0
      IF(NOFTIM.EQ.1) GO TO 1119
      TIACS=0.0
      INOTIM=2
      GO TO 1124
 1121 IHARV(JFK)=IFK
      IFIELD(IFK)=JFK
C
C        SELECTED NEW FIELD (IFK) FOR HARVESTER (JFK)
C
```

```
      IF(IDAL.GE.50) GO TO 1161
      IF(MATRTE(IFK,IDAL).GE.0.9999) GO TO 1161
      DO 1160 IDA1=IDAL,50
      MATRTE(IFK,IDA1)=(MATRTE(IFK,IDA1)-MATRTE(IFK,IDAL))/(1.0-MATRTE(I
     1FK,IDAL))
      WRITE(3,7112) MATRTE(IFK,IDA1),IDA1
7112  FORMAT(' ','MAT   ',F10.5,'   IDA1   ',I10)
1160  CONTINUE
 1161 CONTINUE
C
C         OPENING RATE IS ADJUSTED TO REMAINING COTTON
C         IN THE FIELD, AFTER FIELD IS HARVESTED 1 TIME.
C
C
 1119 CONTINUE
      IQUIT=0
      DO 1122 JFK=1,NHVS
1122  IF(IHARV(JFK).EQ.0) IQUIT=IQUIT+1
      IF(IQUIT.EQ.NFLD) GO TO 1123
      GO TO 4
 1123 CONTINUE
 1130 FORMAT('0',10X,'COMPLETED HARVESTING FIELD NO.',I5,5X,'ON DAY',I5,
     15X,'THIS FIELD HAS BEEN HARVESTED',I2,1X,'TIME',/,' ','REMAINING C
     2OTTON IS ',F10.0)
C
C
C       CHECK IF ALL TRAILERS ARE GINNED IF ALL COTTON IS HARVESTED
        DO 5 I=1,NTLS
        IF(TAMT(I).GT.50.0) GO TO 8018
    5 CONTINUE
        GO TO 7
    4 CONTINUE
C
C
        NOH=IDAY
        DO 632 IC=1,NTLS
        IF(IFLAG(IC).EQ.0.OR.IFLAG(IC).EQ.5.OR.IFLAG(IC).EQ.6)TF(IC)=
       1TF(IC)+0.1
  632 TT(IC)=TT(IC)+0.1
C       HARVESTING CALCULATIONS
C       FOR EACH HARVESTER, HARVEST DURING AT
        DO 8 J=1,NHVS
        IF(IHARV(J).EQ.0) GO TO 8
        IF(TIDT.LT.ISH(J))GO TO 8
C       BREAK DOWN OCCURS EVERY  8 HOURS ON AVERAGE AND REQUIRES 1.2 HOURS
C              FOR REPAIR ON AVERAGE
        BH=1.-EXP(-0.1/8.0)
        X(1)=X(1)*8192.*16384.
        CALL RANDU(X,NN)
        RNX=X(1)
        IF(RNX.GT.BH) GO TO 1061
        SUH=0.
        DO 1062 IR=1,4
        X(1)=X(1)*8192.*16384.
        CALL RANDU(X,NN)
 1062   SUH=SUH+X(1)
        RNX=X(1)
        DTH=12.*ALOG(1.-RNX)
        WRITE(3,1063) J,IDT,IDAY,DTH
 1063   FORMAT(' ','HARVESTER NO.',I4,'BREAKS DOWN, TIME',I4,'OF DAY',I4,
       16X,'REPAIR TIME IS',F6.1,'TIME INCREMENTS')
        ISH(J)=TIDT+ABS(DTH)
 1061   CONTINUE
C       LBH=POUNDS OF SEED COTTON PER BALE
        LBH=(479./GTO)*100
        IU=IHARV(J)
        YAK=YA(IU       )*MATRTE(IU       ,IDAL)
        SYA=YAK/6.0
        CALL  GAUSS(X,NN,SYA,YAK,VYA)
        IF(VYA.GT.1.25)VEL=5.-1.33*(VYA-1.25)
        AO= VEL*6.67      /8.25
C       AO=ACRES PER HOUR,THEORETICAL
C       TWO=THEORETICAL TIME PER ACRE
C       IF ALL COTTON HAS BEEN HARV, CHECK ON TRAILER STATUS
C       XO=AMT HELD BY EA. HARV, LBS.
        TWO=1./AO
        A=8910.89/(2.*VEL)
        B=163.4/(2.*RL(IU        )/1200.)
        XO=LBH*HARCAP
```

```
      C=90.*LBH*VYA/XO
      IF(IUT.EQ.60) WRITE(3,1010) A,B,C,EFF
 1010 FORMAT(' ',3F8.1,6X,F8.3,6X,'A,B,C,EFF')
      DT=600.0*(YA(IU        )*MATRTE(IU         ,IDAL)/TCAP)
      EFF=A/((6./5.)*(A+B+C+DT))
      TACRE=TOO/EFF
C     ACDELT IS ACRES HARV IN DELTA T
      ACDELT=(1./TACRE)*0.1
      RTRIP=(RL(IU        )/6534.)*2.
C     TRAILERS AND A HAULER ARE READY, HAUL TO GIN.
      TTRIP=TACRE*RTRIP
C     IF AT THE START OF THIS TIME PERIOD, A HARV. IS FULL, IT IS ASSUME
C              TO BE IDLE
      P11=479.0/(GTO*13000.0)
      HARTOL=P11*YA(IU        )*RL(IU         )*2.0*MATRTE(IU         ,IDAL)
      IF(HARTOL.GT.500) HARTOL=500.
      IF(HAMT(J).GT.XO-HARTOL) GO TO 10
C     AIDT=AMT. IN HARVESTER DURING DELTA-T
      AIDT=(1./TACRE)*0.1*VYA*LBH
C     HAMT(J)=AMT. IN JTH HARV.
      HAMT(J)=HAMT(J)+AIDT
      TACS(IU        )=TACS(IU         )+ACDELT
      TTACS=TTACS+ACDELT
      COTT(IU        )=COTT(IU         )-AIDT
      IF(COTT(IU        ).LT.0.0) COTT(IU         )=0.0
      TCN=TCN+AIDT
C        IF THE HARV. BASKET IS WITHIN HARTOL LBS
C        OF CAPACITY, THEN IT IS
C         DUMPED, OTHERWISE, LOOK FOR NEXT HARV.
      IF(HAMT(J).LE.XO-HARTOL) GO TO 8
C
   10 CONTINUE
C     LOOK AT TRAILERS TO SEE IF WE CAN DUMP HARV.
C     CHECKS FOR EMPTY TRAILERS; IF ONE IS EMPTY, THE FLAG IS SET FOR
C              FILLING IT
      DO 11 K=1,NTLS
      IF(IFLAG(K).EQ.1.AND.NSGN(K).EQ.J) GO TO 12
   11 CONTINUE
      DO 37 K=1,NTLS
      IF(IFLAG(K).EQ.0) NSGN(K)=J
      IF(IFLAG(K).EQ.0) IFLAG(K)=1
      IF(IFLAG(K).EQ.1.AND.NSGN(K).EQ.J) WRITE(3,601)K,IDT,IDAY,J
  601 FORMAT(' ','TRAILER NO.',I3,2X,'IS SELECTED TO BE FILLED AT TIME',
     1I4,2X,'OF DAY',I4,2X,'BY HARVESTER',I2)
      IF(IFLAG(K).EQ.1.AND.NSGN(K).EQ.J) GO TO 12
   37 CONTINUE
C     NSGN(K)=ASSIGNING THE KTH TRAILER TO THE JTH HARV.
C     IFLAG=0 MEANS TRAILER WAITING TO BE FILLED
C     IFLAG=1 MEANS TRAILER IS BEING LOADED
C     IFLAG=2 MEANS TRAILER IS FULL
C     IFLAG=3 MEANS TRAILER IS IN TRANSIT TO GIN
C     IFLAG=4 MEANS TRAILER IS IN QUEUE
C     IFLAG=5 MEANS TRAILER EMPTY AND ON GIN YARD
C     IFLAG=6 MEANS TRAILER ON WAY HOME
C     IF DO LOOP COMPLETED, NO TRAILER AVAIL.
C     JFLAG(J)=0 LETS HARV DUMP
C     JFLAG(J)=1 MEANS IDLE HARV.
      JFLAG(J)=1
      IDL(J)=IDL(J)+0.1
      GO TO 8
C
C     FILLING THE K+H TRAILER FROM THE J+H HARVESTER
   12 TAMT(K)=TAMT(K)+HAMT(J)
      IF(TAMT(K).GT.TCAP-500.)IFLAG(K)=2
      IF(IFLAG(K).EQ.2)WRITE(3,602)K,IDT
  602 FORMAT(' ','TRAILER NO.',I4,2X,'WAS FILLED AT TIME',I4)
C     CHECKS FOR FULL TRAILERS
      WRITE(3,64)IDAY,IDT,J,HAMT(J),K,TAMT(K),IHARV(J),IDL(J)
   64 FORMAT(' ',6X,'DAY',I4,'TIME',I4,6X,'HARVESTER NO.',I2,'HAS',F8.1,
     1'LBS. OF SEED COTTON BEING DUMPED INTO TRAILER',I3 ,/,' WHICH NOW
     1HAS',F10.1,'LBS. OF SEED COTTON',10X,'FIELD NO.',I5,6X,'IDLE TIME=
     1',F4.0)
C     EMPTIES THE J+H HARV.
      HAMT(J)=0.
      JFLAG(J)=0
    8 CONTINUE
C
C
 8018 IKD=0
```

```
C     AFTER HARV. DURING DELTA T, THE TRAILERS ARE EXAMINED AND IF TWO
      IF(IHLR.NE.0)GO TO 6
C     TO SEE IF ANY TRAILERS LEFT ON FARM; IF SO HE WILL HAUL 1 TRAILER
      DO 83 IT=1,NTLS
      IF(IQUIT.EQ.NHVS.AND.IFLAG(IT).EQ.2) IFLAG(IT)=3
      IF(IFLAG(IT).EQ.3)GO TO 18
   83 CONTINUE
      IRD =0
      DO 17 IT=1,NTLS
      IRDK=0
      IF(IFLAG(IT).EQ. 2)IRDK=1
   17 IRD=IRD+IRDK
      KTT=0
      DO 112 IT=1,NTLS
      KT=0
      IF(IRD.LT.2)GO TO 6
      IF(IFLAG(IT).EQ.2) KT=1
      KTT=KTT+KT
      IF(KT.EQ.1)IFLAG(IT)=3
      IF(IFLAG(IT).EQ.3) WRITE(3,603) IT,IDT
  603 FORMAT(' ','TRAILER NO.',I4,2X,'LEAVES FOR GIN AT TIME',I4)
      IF(KTT.EQ.1) GO TO 18
  112 CONTINUE
      GO TO 6
C     IHLR IS THE PICK-UP DRIVER
C     IHLR=0 ,HE IS ON FARM
C     IHLR=1, HE IS ON WAY TO GIN
C     IHLR=2, HE IS AT GIN
C     IHLR=3, HE IS ON WAY TO FARM
   18 IHLR=1
      NHAUL=NHAUL+1
      TRD=(XMT/15.)*10.
      ENQ=IDT+TRD+2
      TENQ=TIDT+TRD+2
      DO 23 JK=1,NTLS
      IF(IFLAG(JK).NE.3)GO TO 23
      ENT(JK)=TENQ
   23 CONTINUE
C
C
C     GINNING PORTION OF PROGRAM
    6 CONTINUE
      IZ=0
      ARPH=0.
      IF(IDT.GT.IHSTRT.AND.IDT.LT.IHEND) ARPH=(AR/(IHEND-IHSTRT))*10.
      TNBLS=TNBLS+ARPH/10.
C
C     TNBLS=TOTAL NO. OF BALES ARRIVED AT GIN, ACCUMULATED
C     THIS LOOP CHECKS FOR TRAILERS ARRIVING DURING THIS DELTA-T
      DO 27 JL=1,NTLS
      IF(TIDT.LT.ENT(JL).OR.IFLAG(JL).NE.3) GO TO 27
      IF(IHLR.EQ.1)IHLR=2
      IF(IHLR.NE.2) GO TO 27
      IRT=TIDT+2
C     IRTRN=TIME HAULER GETS BACK TO FARM
      IRTRN=IRT+(XMI/15.)*10.
      IF(IFLAG(JL).EQ.3)GO TO 29
C     IGN=TIME THE I+H TRAILER ENTERS THE GIN QUEUE
      TNBLS=TNBLS+TCAP*(GTO/47900.)
      GO TO 27
   29 IFLAG(JL)=4
      IZ=IZ+1
      IGN(JL)=BKLG-X(1)*ARPH*0.1+BGND+(TCAP*GTO/47900.0)
      IF(IZ.EQ.2)IGN(JL)=BKLG-RNX*ARPH*0.1+2.0*(TCAP*GTO/47900.0)+BGND
      WRITE(3,71)JL,IDT,IDAY,BKLG
   71 FORMAT(' ','TRAILER NO.',I4,2X,'ENTERS GIN QUEUE AT TIME',I4,2X,'
     1OF DAY',I4,'. GIN BACKLOG IS',F9.1,2X,'BALES')
   27 CONTINUE
C
      IF(TIDT.EQ.IRTRN.AND.IHLR.EQ.2) IHLR=0
      IF(IGFLG.EQ.1) GO TO 998
      IF(TIDT.LT.GOP) GO TO 999
      IF(BGND.GE.TNBLS-0.7)GO TO 997
C     CALCULATES GIN FAILURE TIMES AND DOWN TIMES, SETS GOP FOR WHEN
C            GIN IS FIXED AND STARTS TO OPERATE AGAIN
      PU=1.-EXP(-0.1/12.)
      Y(1)=X(1)*8192.*16384.
      CALL RANDU(X,NN)
      RNX=X(1)
```

PROGRAM LISTING—Continued

```
      IF(RNX.GT.RO) GOTO 30
C     GIN BREAKS DOWN IF RNX LESS THAN PROB. OF FAILURE
      SUX=0.
      DO 1001 IR=1,4
      X(1)=X(1)*8192.*16384.
      CALL RANDU(X,NN)
 1001 SUX=SUX+X(1)
      RNX=X(1)
C     WITH 10 HERE, IT MEANS 1 HR. AVERAGE REPAIR TIME
      GOT=10.*ALOG(1.-RNX)
      GOP=TIDT+ABS(GOT)
      WRITE(3,604)IDT,IDAY,GOT
  604 FORMAT(' ','GIN BREAKS DOWN AT TIME',I4,2X,'OF DAY',I4,2X,'REPAIR
     1TIME IS',F6.1,2X,'TIME INCREMENTS')
C     ONLY WHEN TIDT IS GREATER THAN GOP DOES GIN BEGIN TO OPERATE AGAIN
   30 CONTINUE
C
C     RANDOMLY COMPUTES AMT GINNED DURING AT
      SGRT=0.6
      CALL GAUSS(X,NN,SGRT,GRTE,GAMT)
      GAMT=GAMT*0.1
      IF(BKLG.LT.0.1) GO TO 996
      IF(GAMT.GT.BKLG) GAMT=BKLG
      DGIN=DGIN+GAMT
      BGND=BGND+GAMT
  996 BKLG=TNBLS-BGND
  997 CONTINUE
      IMPT=0
C
C     IMPT=NO. TRAILERS READY TO BE HAULED BACK TO FARM, MAX. OF 2
C     CHECKS FOR TRAILERS BEING GINNED AND RETURNED TO FARM
      DO 282 I=1,NTLS
      IF(IFLAG(I).NE.4)GO TO 282
      IF(IGN(I).GT.BGND)GO TO 282
      IFLAG(I)=5
      TAMT(I)=0.
      WRITE(3,605)I,IDT
  605 FORMAT(' ','TRAILER NO.',I4,2X,'IS GINNED. TIME IS',I4)
  282 IF(IFLAG(I).EQ.5)IMPT=IMPT+1
      ICNT=0
      DO 40 I=1,NTLS
      IF(IFLAG(I).NE.5)GO TO 41
      IF(IHLR.EQ.1.OR.IHLR.EQ.3)GO TO 41
      IF(IHLR.EQ.0.AND.IMPT.EQ.1) GO TO 41
      IF(IDT.GT.80) GO TO 40
      ICNT=ICNT+1
      RT(I)=TIDT+(XMI/15.)*10.
      IF(IHLR.EQ.0)RT(I)=TIDT+((XMI/15.)*10.)*2.
      IF(ICNT.EQ.2.OR.IHLR.EQ.2)IHLR=3
      IF(ICNT.EQ.2)NHAUL=NHAUL+1
      IFLAG(I)=6
   41 IF(TIDT.GT.RT(I).AND.IFLAG(I).EQ.6) GO TO 111
      GO TO 40
  111 IFLAG(I)=0
      WRITE(3,114)I,IDT,IDAY
  114 FORMAT(' ','TRAILER NO.',I4,2X,'RETURNS TO FARM AT TIME',I4,2X,
     1'OF DAY',I4)
      IHLR=0
   40 CONTINUE
  998 CONTINUE
      IF(IDT.LT.IGT)GO TO 20
      IGT=IGT/10
      WRITE(3,606)
  606 FORMAT('0',//,' ',32X,'DAILY GIN SUMMARY')
      WRITE(3,607)
  607 FORMAT('0',1X,'DAY NO. NO.ARRIVALS  BALES GINNED  TOTAL BALES
     1 TOTAL BALES  CURRENT   OPERATING',/,' ', 12X,'BALES',10X,'TODAY',
     117X, 'RECEIVED',7X,'GINNED',5X,'BACKLOG',3X,'HOURS TODAY'//)
      WRITE(3,608)IDAY,AR,DGIN,TNBLS,BGND,BKLG,IGT
  608 FORMAT(' ',I6,F12.1,F13.1,F12.0,8X,F8.0,F11.1,8X,I3,//)
      IF(IDAY.GT.410.AND.BKLG.LT.2) GO TO 7
      IF(TTACS.GE.ACST) GO TO 999
      WRITE(3,733)
  733 FORMAT('0',6X,'DAILY HARVESTING SUMMARY')
      WRITE(3,615)
  615 FORMAT('0',4X,'HOURS',6X,'TOTAL ACRES    TOTAL COTTON    HARVESTER',
     15X,'WHICH HARVEST',
     1/,'   OPERATION       HARVESTED       HARVESTED       IDLE TIME')
      DO 612 IH=1,NHVS
```

```
612 WRITE(3,613) IH,TTACS,TCN,IDL(IH),INOTIM
613 FORMAT('0',2X,I2,2X,'6',7X,F7.2,7X,F9.1,9X,F5.1,11X,I2,/)
999 CONTINUE
  7 CONTINUE
    CILS = COST PER TRAILER PER YEAR
    CIR= TOTAL COST OF TRAILERS  PER YEAR
    NHAUL = NUMBER OF TRIPS HAULER MAKES TO THE GIN
    CHL = COST PER MILE TO OPERATE PICKUP HAULING,NOT COUNTING LABOR
    CHAUL= TO TAL YEARLY COST FOR HAULING TO GIN
    NIH= TOTAL NO. OF DAYS HARVESTING,INCLUDING RAINY DAYS
    CFLBR=TOTAL COST OF FARM LABOR FOR YEAR
    CGLBR=COST OF GIN LABOR FOR UNLOADING SYSTEM AT GIN
    NGLBR=NO.OF LABORERS FOR THIS GIN UNLOADING SYSTEM
    GCPB=GIN COST PER BALE,FROM SMITH UPDATED STUDY
    VOL=GIN SEASONAL VOLUME
    HPH=HOURS RUN PER HARVESTER
    ASSUME 3 GAL PER HR AT .33 PER GAL.
    CTAX=TAXES/YR.
    CLUB=LUB.COSTS/YEAR
    CINS=INSURANCE COST
    CINT=INTEREST COST
    CDEP=DEPRECIATION COST
    CHARN=TOTAL COST OF HARVESTING FOR YEAR
    CGIN=TOTAL GIN COST FOR YEAR
    TCPB=TOTAL COST PER BALE
    CLOS=YLOS*CCOT*GTO/100.
    CIR=NTLS*CTLS
    CHAUL=NHAUL*CHL*XMI*2.
    NIH=1+NOH-NSH-(NOH-NSH)/7
    CFLBR=(CLBR*8.*NTH)*(NHVS+2+NHVS/3)
    CGLBR=(CLBR*TIDT/10.)*NGLBR
    GCPB=15.98+(24028.65+2547.29*GRTE)/BGND
    HPH=(1.0/(ACDELT*10.0))*ACST/NHVS
    CFUEL=HPH*0.99
    CLUB=0.15*CFUEL
    CTAX=0.01*HARC
    CINS=0.005*HARC
    CINT=((HARC+SV)/2.)*0.07
    CDEP=(HARC-SV)/LIFE
    CREP=0.01*HARC
    CHARV=CFUEL+CLUB+CTAX+CINS+CINT+CDEP+CREP
    CHARV=CHARV*NHVS
    BLLS=TCN*(GTO/100.)/479.
    CGIN=GCPB*BLLS
    TCPB=GCPB+(CHARV+CTR+CHAUL+CFLBR+CLOS)/BLLS
    WRITE (6,635)
    DO 634 IC=1,NTLS
    TT(IC)=TT(IC)-TE(IC)
634 WRITE(3,633) IC,TE(IC),TT(IC)
635 FORMAT('0',10X,'TRAILER UTILIZATION',//,4X,'TRAILER',6X,'EMPTY',
   16X,'FULL')
633 FORMAT(' ',7X,I3,7X,F6.1,5X,F9.1)
    WRITE(3,1080) BLLS,HPH,NTH,CLOS
1080 FORMAT(' ','BALES HARVESTED-',F6.1,//,' ','HOURS OPERATION PER HAR
   1VESTER-',F7.2,//,' ','DAYS LABOR CHARGED FOR HARVESTING',I5,//,' '
   2,'LOST COTTON COST-',F8.2)
    WRITE (6,502) IYR , CHAUL , CFLBR , CHARV , CGIN , TCPB
502       FORMAT ('0', 10X , 'YEAR-NO' , I2 , / ,'HHAULING COST', 8X ,
   1F8.2 ,/, 'FFARM LABOR COST', 5X , F8.2 ,/, 'HHARVESTER COST',5X ,
   1F9.2 ,/,'GGINNING COST', 8X , F8.2 ,/, 1X , 28(1H*) , // ,'TTOTAL
   1COST PER BALE IS', F6.2 ,'FOR HARVESTING , HAULING , AND GINNING',
   1F6.2,2X,'BALES')
    IF(IYR.LT.NYR)GO TO 1000
    STOP
    END


    SUBROUTINE SELECT(N,M,X,NN,PSTART,MASTRT,MATRTE)
    DIMENSION  MATRTE(50,50)
    NSG=GIN STARTING DATE
    NSH=HARVESTING STARTING DATE
    XN=AVG. GIN STARTING DATE
    XM=AVG. FIRST HARV. DATE
    SN AND SM ARE MEASURES OF VARIATION
    XN=287.
    XM=308.
```

```
      SN=3.
      CALL GAUSS(X,MN,SN,XN,G)
      N=G
      DO 1I=1,50
      IF(MATRTE(1,I).LT.PSTART)GO TO 1
      M=MASTRT+I+1
      GO TO 2
    1 CONTINUE
    2 RETURN
      END


      SUBROUTINE DELAYH(X,NN,R,IDAY,ISTART,IRAIN,RFIN)
      DIMENSION RFIN(400),X(1)
C     R=RAINFALL, INCHES
      IF(IRAIN.EQ.1) GO TO 20
      CALL RAIN(R,X,NN)
      GO TO 30
   20 R=RFIN(IDAY)
   30 CONTINUE
      XR1=0.6
      SR1=0.15
      XR2=1.00
      SR2=0.20
      XR3=2.00
      SR3=0.40
C     THE PREC. VARIABLES DESCRIBE A DELAY STEP FUNCTION WHERE STEP
C     BREAK POINTS ARE RANDOMLY CHOSEN
      IF(R.LT.0.01) GO TO 71
      CALL GAUSS(X,NN,SR1,XR1,DLMT1)
      CALL GAUSS(X,NN,SR2,XR2,DLMT2)
      IF(R.LT.DLMT1)DLAY=3.
      IF(R.GT.DLMT1.AND.R.LT.DLMT2)DLAY=4.
      IF(R.GT.DLMT2)DLAY=5.
   72 IDLAY=DLAY+0.1
      IF(ISTART.GT.IDAY)ISTART=ISTART+IDLAY
      ISTART=IDAY+IDLAY
      IF(ISTART-IDAY.GT.4)ISTART=IDAY+4
C     A MAX DELAY OF 4 DAYS FROM CURRENT DAY
      IF(R.GE.0.01)WRITE(3,61)IDAY,R,ISTART
   61 FORMAT('0','DAY NO.=',I4,4X,'RAIN=',F5.2,4X,'DELAY UNTIL DAY=',I4)
   71 CONTINUE
      RETURN
      END


      SUBROUTINE RAIN(R,X,NN)
      DIMENSION X(1)
      R=0.
      RETURN
      END


      SUBROUTINE ARR(R,X,NN,AR,NDAY,IG,VOL,IAR,SA,NA,NB,NC,IARFLG)
      REAL NA,NB,NC
      DIMENSION X(1)
      IG=0
      DATA NBLNK/0/,NSTART/0/
      IF(NDAY.LT.NSTART) IG=1
      IF(NDAY.LT.NSTART)GO TO 1
      IF(R.GT.0)GO TO 2
      IF(IAR.GT.0) GO TO 1
      XA=NDAY-NBLNK
      IF(IARFLG.EQ.1) GO TO 10
      SA=148.456/((VOL)**0.4426)
      SA=3.37
      NA=0.0027*VOL-3.52-6.0
      NB=100./SA+0.67*NA-2.67
      NC=NB+8.
   10 FOX=((XA/NA)**2)*SA
```

PROGRAM LISTING—Continued

```
      IF(XA.GT.NA)FOX=SA
      IF(XA.GT.NB)FOX=(((NC-XA)/8.)**2)*SA
      IF(XA.GT.NC)FOX=0.
      AAR=FOX*VOL/100.
      ARSIG=AAR/2.5
      CALL GAUSS(X,NN,ARSIG,AAR,AR)
      IF(AR.LT.0.)AR=0.
      GO TO 3
 2    N=1.5*X(1)
      IG=N
      NSTART=NDAY+N
 1    NBLNK=NBLNK+1
      AR=0
 3    RETURN
      END


      SUBROUTINE GAUSS(X,NN,S,AM,Y)
      DIMENSION X(1)
      A=0.0
      DO 50 I=1,12
      X(1)=X(1)*8192.*16384.
      CALL RANDU(X,NN)
      Y=X(1)
50    A=A+Y
      Y=(A-6.0)*S+AM
      RETURN
      END


      SUBROUTINE RANDU(X,N)
      DIMENSION X(1)
      K=316227
      NK=N*K
      RN=N
      R=RN/34359738367.
      X(1)=ABS(R)
      N=NK
      RETURN
      END
```

EXAMPLE RUN

Input Data

```
 1     1     14     6      1           2.5         18.5         1.60         12.0         0.10
  25.10           0.93     200.00
  20.00           1.00     400.00
   5.00           1.40     250.00
  12.50           1.20      75.00
  51.10           1.00     250.00
  30.00           1.00     400.00
 305
0.000.000.080.080.100.100.100.100.100.200.200.200.250.250.300.300.300.300.350.40
0.400.400.500.500.500.600.650.700.700.700.800.800.800.900.900.900.900.900.900.90
0.950.950.950.951.001.001.001.001.001.000.000.000.000.000.000.100.100.100.100.20
0.200.300.400.400.400.400.400.400.500.500.500.500.500.500.500.500.700.700.800.80
0.900.900.950.951.001.001.001.001.001.001.001.001.001.001.001.001.001.001.001.00
0.000.000.080.080.100.100.100.100.100.200.200.200.250.250.300.300.300.300.350.40
0.400.400.500.500.500.600.650.700.700.700.800.800.800.900.900.900.900.900.900.90
0.950.950.950.951.001.001.001.001.001.000.000.000.000.000.000.100.100.100.100.20
0.200.300.400.400.400.400.400.400.500.500.500.500.500.500.500.500.700.700.800.80
0.900.900.950.951.001.001.001.001.001.001.001.001.001.001.001.001.001.001.001.00
0.000.060.080.080.100.100.100.100.200.200.200.250.250.300.300.300.300.350.40
0.400.400.500.500.500.600.650.700.700.700.800.800.800.900.900.900.900.900.900.90
0.950.950.950.951.001.001.001.001.001.000.000.000.000.000.000.100.100.100.100.20
0.200.300.400.400.400.400.400.400.500.500.500.500.500.500.500.500.700.700.800.80
0.900.900.950.951.001.001.001.001.001.001.001.001.001.001.001.001.001.001.001.00

  108.30        0.059    7149.00  13175.00    3000.00     8    1584.00
     5.0        0.28         5.0       3.37   12    34    42     1
  1   10
322   .22   327   .15   335   .02   336   .02   337   .47   340   .36   343   .01   344   .02
350   .04   363   .01
   0.002    40   100        0.800
  1  314   333     4
```

Output Data

```
        HARVEST-GIN  FOR N.C. STATE EXAMPLE

                    NO.HARV.   NO.TRAILERS   TRAILER CAP.   DIST.TO GIN

                       1          14           7767.6          2.5

  FIELD                  ACRES                YIELD        ROW LENGTH
    1                    25.10                  .93          200.00
    2                    20.00                 1.00          400.00
    3                     5.00                 1.40          250.00
    4                    12.50                 1.20           75.00
    5                    51.10                 1.00          250.00
    6                    30.00                 1.00          400.00
GIN STARTING DAY IS 314

HARV. STARTING DAY IS 333

TOTAL COTTON TO HARVEST IS  379168.6POUNDS


      DAILY HARVESTING SUMMARY

    HOURS      TOTAL ACRES    TOTAL COTTON   HARVESTER      WHICH HARVEST
  OPERATION     HARVESTED      HARVESTED     IDLE TIME

   1  6            .00             .0            .0             1

GIN BREAKS DOWN AT TIME  87  OF DAY 319  REPAIR TIME IS  -4.2  TIME INCREMENTS


                              DAILY GIN SUMMARY

DAY NO.  NO.ARRIVALS   BALES GINNED  TOTAL BALES     TOTAL BALES   CURRENT    OPERATING
            BALES         TODAY        RECEIVED        GINNED.     BACKLOG   HOURS TODAY


  319        38.1          37.4          90.             90.          .6         11
```

Output Data—Continued

DAILY HARVESTING SUMMARY

HOURS OPERATION	TOTAL ACRES HARVESTED	TOTAL COTTON HARVESTED	HARVESTER IDLE TIME	WHICH HARVEST
1 6	.00	.0	.0	1

DAILY GIN SUMMARY

DAY NO.	NO. ARRIVALS BALES	BALES GINNED TODAY	TOTAL BALES RECEIVED	TOTAL BALES GINNED	CURRENT BACKLOG	OPERATING HOURS TODAY
320	39.9	39.2	130.	129.	.7	11

DAILY HARVESTING SUMMARY

HOURS OPERATION	TOTAL ACRES HARVESTED	TOTAL COTTON HARVESTED	HARVESTER IDLE TIME	WHICH HARVEST
1 6	.00	.0	.0	1

DAILY GIN SUMMARY

DAY NO.	NO. ARRIVALS BALES	BALES GINNED TODAY	TOTAL BALES RECEIVED	TOTAL BALES GINNED	CURRENT BACKLOG	OPERATING HOURS TODAY
321	84.6	69.4	213.	198.	14.4	11

DAILY HARVESTING SUMMARY

HOURS OPERATION	TOTAL ACRES HARVESTED	TOTAL COTTON HARVESTED	HARVESTER IDLE TIME	WHICH HARVEST
1 6	.00	.0	.0	1

DAILY GIN SUMMARY

DAY NO.	NO. ARRIVALS BALES	BALES GINNED TODAY	TOTAL BALES RECEIVED	TOTAL BALES GINNED	CURRENT BACKLOG	OPERATING HOURS TODAY
333	247.5	357.9	847	847.	.0	23

DAILY HARVESTING SUMMARY

HOURS OPERATION	TOTAL ACRES HARVESTED	TOTAL COTTON HARVESTED	HARVESTER IDLE TIME	WHICH HARVEST
1 6	5.98	10148.9	.0	1

```
                                                                      BY HARVESTER 1
TRAILER NO.   2  IS SELECTED TO BE FILLED AT TIME  43  OF DAY 334   OF SEED COTTON BEING DUMPED INTO TRAILER  2
      DAY 334TIME  43          HARVESTER NO. 1HAS  2075.1LBS.  FIELD NO.    1         IDLE TIME=  0.
WHICH NOW HAS     2075.1LBS. OF SEED COTTON                 REPAIR TIME IS  -1.9TIME INCREMENTS
HARVESTER NO.    1BREAKS DOWN, TIME  470F DAY 334           REPAIR TIME IS -10.0TIME INCREMENTS
HARVESTER NO.    1BREAKS DOWN, TIME  480F DAY 334           OF SEED COTTON BEING DUMPED INTO TRAILER  2
      DAY 334TIME  57          HARVESTER NO. 1HAS  2227.3LBS.  FIELD NO.    1         IDLE TIME=  0.
WHICH NOW HAS     4302.5LBS. OF SEED COTTON
                                   .516        A,B,C,EFF
   891.1   430.2    68.1                                  OF SEED COTTON BEING DUMPED INTO TRAILER  2
      DAY 334TIME  64          HARVESTER NO. 1HAS  2197.5LBS.  FIELD NO.    1         IDLE TIME=  0.
WHICH NOW HAS     6500.0LBS. OF SEED COTTON
TRAILER NO.    2  WAS FILLED AT TIME  71                  OF SEED COTTON BEING DUMPED INTO TRAILER  2
      DAY 334TIME  71          HARVESTER NO. 1HAS  2305.1LBS.  FIELD NO.    1         IDLE TIME=  0.
WHICH NOW HAS     8805.1LBS. OF SEED COTTON
TRAILER NO.    1  LEAVES FOR GIN AT TIME  71                                GIN BACKLOG IS     6.5  BALES
TRAILER NO.    1  ENTERS GIN QUEUE AT TIME  75  OF DAY 334.
                                                                      BY HARVESTER 1
TRAILER NO.    3  IS SELECTED TO BE FILLED AT TIME  77  OF DAY 334   OF SEED COTTON BEING DUMPED INTO TRAILER  3
      DAY 334TIME  77          HARVESTER NO. 1HAS  2098.0LBS.  FIELD NO.    1         IDLE TIME=  0.
WHICH NOW HAS     2098.0LBS. OF SEED COTTON
TRAILER NO.    1  IS GINNED. TIME IS  78                  OF SEED COTTON BEING DUMPED INTO TRAILER  3
      DAY 334TIME  84          HARVESTER NO. 1HAS  2406.7LBS.  FIELD NO.    1         IDLE TIME=  0.
WHICH NOW HAS     4504.7LBS. OF SEED COTTON               OF SEED COTTON BEING DUMPED INTO TRAILER  3
      DAY 334TIME  90          HARVESTER NO. 1HAS  2074.4LBS.  FIELD NO.    1         IDLE TIME=  0.
WHICH NOW HAS     6579.2LBS. OF SEED COTTON
TRAILER NO.    3  WAS FILLED AT TIME  97                  OF SEED COTTON BEING DUMPED INTO TRAILER  3
      DAY 334TIME  97          HARVESTER NO. 1HAS  2387.5LBS.  FIELD NO.    1         IDLE TIME=  0.
WHICH NOW HAS     8966.7LBS. OF SEED COTTON
TRAILER NO.    2  LEAVES FOR GIN AT TIME  97                                GIN BACKLOG IS     9.1  BALES
TRAILER NO.    2  ENTERS GIN QUEUE AT TIME 101   OF DAY 334.
```

Output Data—Continued

DAILY GIN SUMMARY

DAY NO.	NO.ARRIVALS BALES	BALES GINNED TODAY	TOTAL BALES RECEIVED	TOTAL BALES GINNED	CURRENT BACKLOG	OPERATING HOURS TODAY
334	110.3	108.0	956.	955.	.5	11

DAILY HARVESTING SUMMARY

HOURS OPERATION	TOTAL ACRES HARVESTED	TOTAL COTTON HARVESTED	HARVESTER IDLE TIME	WHICH HARVEST
1 6	16.72	27889.5	.0	1

YLOS= .00

DAILY GIN SUMMARY

DAY NO.	NO.ARRIVALS BALES	BALES GINNED TODAY	TOTAL BALES RECEIVED	TOTAL BALES GINNED	CURRENT BACKLOG	OPERATING HOURS TODAY
360	180.5	361.9	3010.	3000.	10.3	23

DAILY HARVESTING SUMMARY

HOURS OPERATION	TOTAL ACRES HARVESTED	TOTAL COTTON HARVESTED	HARVESTER IDLE TIME	WHICH HARVEST
6	109.17	269287.1	.0	1

```
YLOS=    3641.90
TRAILER NO.   1  RETURNS TO FARM AT TIME    5  OF DAY 361
TRAILER NO.   2  RETURNS TO FARM AT TIME    5  OF DAY 361
TRAILER NO.   4  RETURNS TO FARM AT TIME    9  OF DAY 361
TRAILER NO.   5  RETURNS TO FARM AT TIME    9  OF DAY 361
TRAILER NO.   3  IS GINNED. TIME IS  43
TRAILER NO.   1  IS SELECTED TO BE FILLED AT TIME  44  OF DAY 361  BY HARVESTER 1
      DAY 361TIME  44       HARVESTER NO. 1HAS  2399.6LBS. OF SEED COTTON BEING DUMPED INTO TRAILER  1
WHICH NOW HAS     2399.6LBS. OF SEED COTTON               FIELD NO.    5       IDLE TIME=  0.
      DAY 361TIME  48       HARVESTER NO. 1HAS  2262.3LBS. OF SEED COTTON BEING DUMPED INTO TRAILER  1
WHICH NOW HAS     4661.9LBS. OF SEED COTTON               FIELD NO.    5       IDLE TIME=  0.
      DAY 361TIME  52       HARVESTER NO. 1HAS  2179.6LBS. OF SEED COTTON BEING DUMPED INTO TRAILER  1
WHICH NOW HAS     6841.5LBS. OF SEED COTTON               FIELD NO.    5       IDLE TIME=  0.
TRAILER NO.   1  WAS FILLED AT TIME  57
      DAY 361TIME  57       HARVESTER NO. 1HAS  2567.5LBS. OF SEED COTTON BEING DUMPED INTO TRAILER  1
WHICH NOW HAS     9409.0LBS. OF SEED COTTON               FIELD NO.    5       IDLE TIME=  0.
TRAILER NO.   1  LEAVES FOR GIN AT TIME  57
HARVESTER NO.   1BREAKS DOWN, TIME  60OF DAY 361       REPAIR TIME IS  -3.3TIME INCREMENTS
   893.0   392.2    98.7          .546      A.B.C.EFF
TRAILER NO.   1  ENTERS GIN QUEUE AT TIME  61   OF DAY 361. GIN BACKLOG IS     81.0  BALES
TRAILER NO.   3  RETURNS TO FARM AT TIME  63  OF DAY 361
TRAILER NO.   2  IS SELECTED TO BE FILLED AT TIME  64  OF DAY 361  BY HARVESTER 1
      DAY 361TIME  64       HARVESTER NO. 1HAS  2356.2LBS. OF SEED COTTON BEING DUMPED INTO TRAILER  2
WHICH NOW HAS     2356.2LBS. OF SEED COTTON               FIELD NO.    5       IDLE TIME=  0.
      DAY 361TIME  68       HARVESTER NO. 1HAS  2112.0LBS. OF SEED COTTON BEING DUMPED INTO TRAILER  2
WHICH NOW HAS     4468.2LBS. OF SEED COTTON               FIELD NO.    5       IDLE TIME=  0.

         COMPLETED HARVESTING FIELD NO.    5     ON DAY  361     THIS FIELD HAS BEEN HARVESTER 1 TIME
REMAINING COTTON IS       1573.


YA       .01189
      DAY 361TIME  72       HARVESTER NO. 1HAS  2418.6LBS. OF SEED COTTON BEING DUMPED INTO TRAILER  2
WHICH NOW HAS     6886.8LBS. OF SEED COTTON               FIELD NO.    6       IDLE TIME=  0.
TRAILER NO.   2  WAS FILLED AT TIME  76
      DAY 361TIME  76       HARVESTER NO. 1HAS  2382.9LBS. OF SEED COTTON BEING DUMPED INTO TRAILER  2
WHICH NOW HAS     9269.7LBS. OF SEED COTTON               FIELD NO.    6       IDLE TIME=  0.
TRAILER NO.   2  LEAVES FOR GIN AT TIME  76
TRAILER NO.   3  IS SELECTED TO BE FILLED AT TIME  80  OF DAY 361  BY HARVESTER 1
      DAY 361TIME  80       HARVESTER NO. 1HAS  2389.8LBS. OF SEED COTTON BEING DUMPED INTO TRAILER  3
WHICH NOW HAS     2389.8LBS. OF SEED COTTON               FIELD NO.    6       IDLE TIME=  0.
TRAILER NO.   2  ENTERS GIN QUEUE AT TIME  80   OF DAY 361. GIN BACKLOG IS    156.4  BALES
      DAY 361TIME  84       HARVESTER NO. 1HAS  2334.3LBS. OF SEED COTTON BEING DUMPED INTO TRAILER  3
WHICH NOW HAS     4724.1LBS. OF SEED COTTON               FIELD NO.    6       IDLE TIME=  0.
      DAY 361TIME  88       HARVESTER NO. 1HAS  2320.7LBS. OF SEED COTTON BEING DUMPED INTO TRAILER  3
WHICH NOW HAS     7044.9LBS. OF SEED COTTON               FIELD NO.    6       IDLE TIME=  0.
```

Output Data—Continued

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TRAILER NO.    3  WAS FILLED AT TIME  92
        DAY 361TIME  92        HARVESTER NO. 1HAS  2480.9LBS. OF SEED COTTON BEING DUMPED INTO TRAILER  3
WHICH NOW HAS     9525.8LBS. OF SEED COTTON            FIELD NO.    6       IDLE TIME=  0.
TRAILER NO.    3  LEAVES FOR GIN AT TIME  92
GIN BREAKS DOWN AT TIME  92  OF DAY 361  REPAIR TIME IS -11.0  TIME INCREMENTS
TRAILER NO.  4  IS SELECTED TO BE FILLED AT TIME  96  OF DAY 361  BY HARVESTER 1
        DAY 361TIME  96        HARVESTER NO. 1HAS  2634.2LBS. OF SEED COTTON BEING DUMPED INTO TRAILER  4
WHICH NOW HAS     2634.2LBS. OF SEED COTTON            FIELD NO.    6       IDLE TIME=  0.
TRAILER NO.    3  ENTERS GIN QUEUE AT TIME  96   OF DAY 361. GIN BACKLOG IS    208.2  BALES
        DAY 361TIME 100        HARVESTER NO. 1HAS  2572.8LBS. OF SEED COTTON BEING DUMPED INTO TRAILER  4
WHICH NOW HAS     5207.1LBS. OF SEED COTTON            FIELD NO.    6       IDLE TIME=  0.


          TRAILER UTILIZATION

   TRAILER        EMPTY        FULL
         1          21.0            55.2
         2          34.7            41.5
         3          44.2            32.0
         4          50.7            25.5
         5          28.9            47.3
         6          57.6            18.6
         7          69.5             6.7
         8          71.1             5.1
         9          76.2              .0
        10          76.2              .0
        11          76.2              .0
        12          76.2              .0
        13          76.2              .0
        14          76.2              .0
BALES HARVESTED- 140.0

HOURS OPERATION PER HARVESTER-  59.58

DAYS LABOR CHARGED FOR HARVESTING   31

HARVESTER COST        2235.20
GINNING COST          3456.99
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TOTAL COST PER BALE IS 61.77FOR HARVESTING , HAULING , AND GINNING


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